MULTI-DEPENDENT CRITERIA SUPPLIER SELECTION WITH UNCERTAIN PERFORMANCE EVALUATION

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หนึ่งในปัจจัยหลักที่จะช่วยปรับปรุงประสิทธิภาพด้านโลจิสติกส์ขององค์กรได้คือการคัดเลือกผู้ส่งมอบที่เหมาะสม ในการคัดเลือกผู้ส่งมอบนั้นมีเกณฑ์ในการตัดสินใจหลายด้าน อีกทั้งผู้ส่งมอบที่มีประสิทธิภาพเฉลี่ยในอดีตสูงไม่จำเป็นต้องเป็นผู้ส่งมอบที่เหมาะสมที่สุดเสมอไป เนื่องจากความไม่แน่นอนที่ทำให้ผลการดำเนินงานเปลี่ยนแปลง วัตถุประสงค์ของงานวิจัยนี้คือพัฒนาวิธีการคัดเลือกผู้ส่งมอบที่คำนึงถึงความไม่แน่นอนของผลการดำเนินงาน โดยคำนึงถึงประสิทธิภาพเฉลี่ย ความแปรปรวน และความเบ้ของผลการดำเนินงาน และระบุปัจจัยที่มีผลต่อการตัดสินใจคัดเลือกผู้ส่งมอบสำหรับอุตสาหกรรมอิเล็กทรอนิกส์ในประเทศไทย งานวิจัยนี้ได้กำหนดปัจจัยหลักในการคัดเลือกผู้ส่งมอบจำนวน 6 ปัจจัย และมีปัจจัยรองรวมจำนวน 13 ปัจจัย การเก็บข้อมูลวิจัยใช้วิธีการสัมภาษณ์เชิงลึกและการใช้แบบสอบถาม พบว่าปัจจัยที่มีผลต่อการคัดเลือกผู้ส่งมอบมากที่สุดสามอันดับแรกคือ ระยะเวลาในการรอคอยสินค้า ราคา และ ความสามารถในการปรับปรุงอย่างต่อเนื่อง ซึ่งมีน้ำหนักความสำคัญเท่ากับ 0.0910, 0.0869 และ 0.0806 ตามลำดับ จากการวิเคาะห์ผลของความเบ้ พบว่า ความเบ้มีผลต่อผลการดำเนินงานมากกว่าค่าเฉลี่ยและส่วนเบี่ยงเบนมาตรฐาน โดยความเบ้สามารถแยกความแตกต่างระหว่างผู้ส่งมอบซึ่งผู้ซื้อคำนึงถึงเป็นอันดับแรกและผู้ส่งมอบที่ผู้ซื้อคำนึงถึงเป็นลำดับสุดท้ายได้มากกว่าผลดำเนินงานเฉลี่ยและส่วนเบี่ยงเบนมาตรฐาน แสดงให้เห็นว่าความเบ้มีผลต่อผลการดำเนินงานมากกว่าค่าเฉลี่ยและส่วนเบี่ยงเบนมาตรฐานและไม่ควรถูกละเลยเมื่อต้องทำการเปรียบเทียบประสิทธิภาพของผู้ส่งมอบ ดังนั้น งานวิจัยนี้จึงได้พัฒนาตารางการตัดสินใจสำหรับปัญหาการคัดเลือกผู้ส่งมอบที่คำนึงถึงความเบ้ ซึ่งเรียกว่าการวิเคราะห์แนวโน้มความสำเร็จและความเบ้ (Success Mode Skewness Analysis: SMSA) จากการตรวจสอบความถูกต้องของตารางการตัดสินใจที่พัฒนาขึ้น พบว่า มีความถูกต้องมากกว่าการพิจารณาเฉพาะค่าเฉลี่ยและส่วนเบี่ยงเบนมาตรฐาน ผลการวิจัยนี้จะเป็นประโยชน์ให้กับทั้งผู้ส่งมอบและผู้ซื้อเพื่อเป็นแนวทางในการพัฒนาประสิทธิภาพด้านโลจิสติกส์

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ORNICHA ANUCHITCHANCHAI: MULTI-DEPENDENT CRITERIA SUPPLIER SELECTION WITH UNCERTAIN PERFORMANCE EVALUATION. ADVISOR: PROF. KAMONCHANOK SUTHIWARTNARUEPUT, Ph.D., CO-ADVISOR: ASSOC. PROF. PONGSA PORNCHAIWISESKUL, Ph.D., 139 pp.

One of the key to improve logistics efficiency of a firm is to select appropriate supplier. In order to select supplier, there are many criteria involved. Also supplier with greatest average performance does not confirm to be the most suitable one because of uncertainties. Therefore the objectives of this research are to develop decision matrix for selecting supplier based on mean-variance-skewness and identify influential criteria of supplier selection problem for Thai electronics industry. In this research, the set of criteria comprises of 6 main criteria with total of 13 sub-criteria. The data was collected via in-depth interview and questionnaire. The first three criteria which have highest important weight are lead time, follows by price, and continuous improvement ability with important weight equal to 0.0910, 0.0869 and 0.0806, respectively. To analyze skewness effect, it is found that skewness has effect on performance more than average and SD. Skewness can better distinguish between first and less priority supplier than considering only mean and SD. This result indicates that skewness really plays important role in supplier performance and should not be ignored when evaluating suppliers. Therefore, this research develops decision matrix for supplier selection including skewness, namely, Success Mode Skewness Analysis (SMSA). The validation of developed decision matrix shows that including skewness into consideration is more valid than considering only mean and SD. The findings have significant implication for both of suppliers and buyers in terms of improving logistics efficiency

Field of Study: Logistics Management Student's Signature .....
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CHAPTER 1
INTRODUCTION

1.1 Introduction

Nowadays businesses tend to compete with rivals by improving capability to meet customer demands. In terms of logistics and supply chain management, there are several activities which a firm should conduct, for example, customer service and support, purchasing and procurement, transportation, inventory management, etc. Among these activities, purchasing and procurement is an activity that manufacturing companies have been facing and focusing due to its significance in company overall effectiveness (Bevilacqua & Petroni, 2002; Ellram & Carr, 1994). In procurement and purchasing process, there are six decisions to make orderly (Aissaoui, Haouari, & Hassini, 2007) as shown in Figure 1.1.

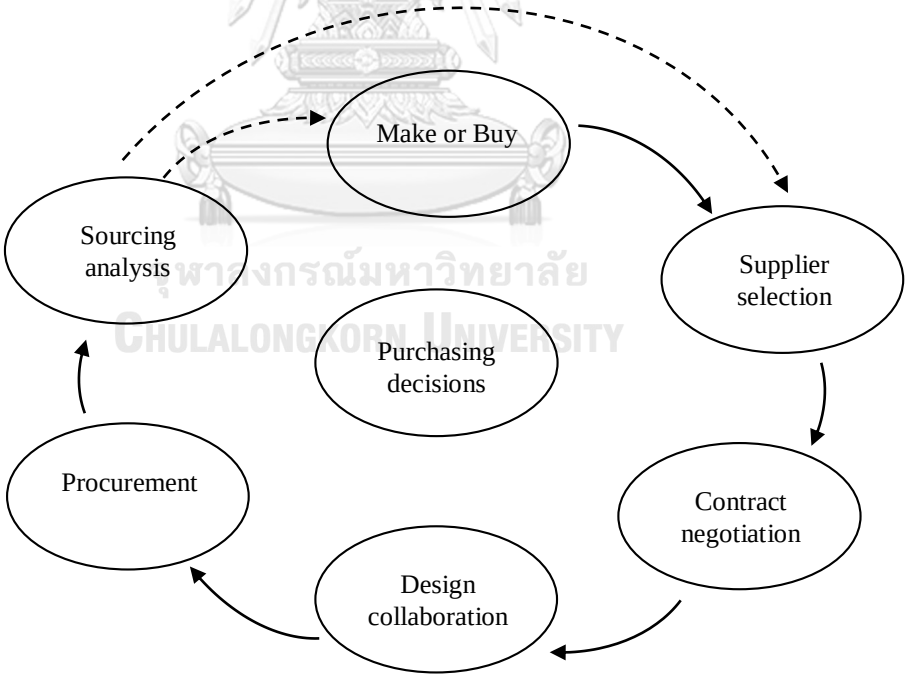


Figure 1.1 Decision processes in purchasing and procurement activity (Aissaoui et al., 2007)

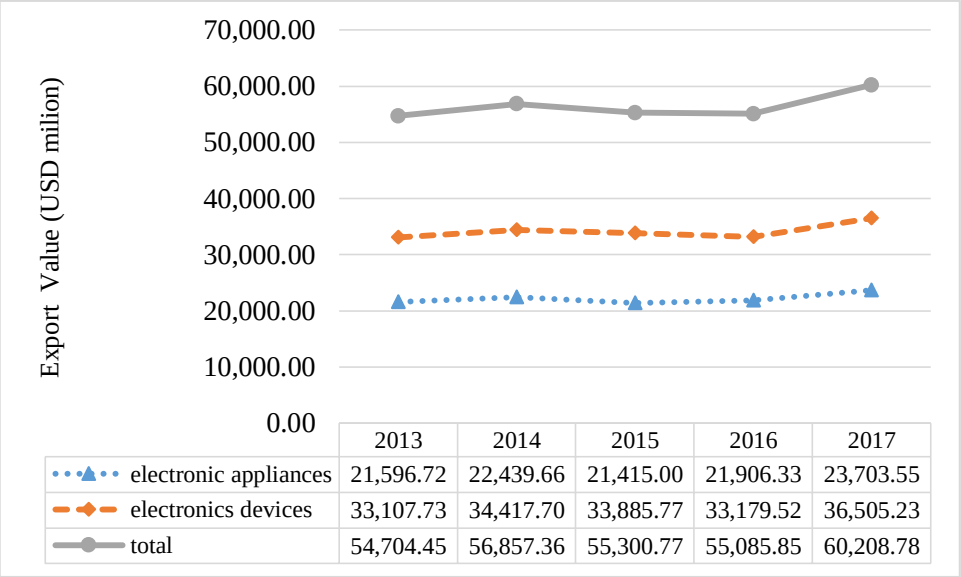
In Figure 1.1, after companies decide whether to make product by themselves or buy from outside, the next step is supplier selection process which means selecting the most suitable supplier who should provide materials, parts, semi-finished parts, etc., to buyer's company in order to produce product by their own or sell to customers with highest efficiency. Then design the contract, how should company negotiate with selected supplier. Next step is design collaboration, co-working with supplier to meet product requirement and specification before start the procurement process. After finish the procurement, company should evaluate efficiency of purchasing and procurement activity, especially supplier performance. From these decision processes, one of the key to improve logistics efficiency of a firm is to select appropriate supplier. To compete with rivals, suppliers play important role on buying firm. Purchasing cost sometimes contribute more than 50% of total cost of goods sold (Humphreys, Huang, Cadden, & McIvor, 2007). Therefore it is obviously that supplier performance has effect on firm performance. On the other hand, supplier selection and evaluation are able to enhance cost and reduction as well as quality Aksoy and Öztürk (2011)

De Boer, Labro, and Morlacchi (2001) stated that supplier selection processes were classified into four phases. After define problem, the criteria must be formulated. Then qualify or pre-select suppliers to reduce number of possible suppliers before making final decision. One of the important questions is how to identify critical criteria as well as its importance level. Since Dickson first introduced 23 critical criteria of supplier selection problem in 1960, many researchers still used Dickson's criteria to evaluate suppliers. It appears that cost, delivery and quality are top-3 basic criteria that most of the studies considered. The next top-2 criteria are production facilities and capacity, and technical capability. Due to different industry and environment, then different criteria are selected. Obviously, supplier selection is the decision making under multiple criteria including qualitative and quantitative criteria that buying firm should consider.

Moreover as the environmental awareness has been growing, numerous researchers in supply chain and logistics management has combined this issue into their researches in many topics. Green manufacturing is one of the crucial issues to enhance green supply chain management. Therefore, in supplier selection process, a firm should

consider criteria of being green supplier chain in terms of promoting green supply chain management for long-term sustainability. In this research, criteria of green supplier are brought to consider with other qualitative and quantitative criteria.

In Thailand, electronics industry is one of the most important industries. Also, refer to Thailand 4.0 development plan, 1 of 10 targeted industries is electronics industry with total export in 2017 accounted for more than 60 billion as showed in Figure 1.2.



	2013	2014	2015	2016	2017
electronic appliances	21,596.72	22,439.66	21,415.00	21,906.33	23,703.55
electronics devices	33,107.73	34,417.70	33,885.77	33,179.52	36,505.23
total	54,704.45	56,857.36	55,300.77	55,085.85	60,208.78

Source: Office of Industrial Economics, Ministry of Industry Thailand

Figure 1.2 Export value of Thai electronics industry

From Figure 1.2, it can be seen that electronics industry in Thailand is continuously expanding. With skillful labor, geographic advantage and transport facilities, Thailand has been being the largest electrical appliances manufacturing base in ASEAN and will continue to play an important role in Thailand's economic development. However, due to ASEAN Economic Community (AEC) that has been established by the end of 2015, despite of gaining new opportunities, the competition among this region is more crucial. Thai manufacturers have to adjust themselves for a situation like this. One of the key issues is improving their performance. Not

surprisingly, supplier selection has positive relationship to buying firm's performance (Kannan & Tan, 2002; Nelson, Muhamad, Loo, & Mat, 2005). Improving supplier selection could affect to manufacturer's performance as well.

Electronics products are different from general consumer products because they are various customization and time sensitive which performance extensively depends on suppliers. In addition, supplier plays a major role in supporting and enhancing buying firm's efficiency (Lemke, Goffin, Szwejczewski, Pfeiffer, & Lohmüller, 2000). There are many researches developing supplier selection method in Asian region. For example, case study in Hong Kong by Choy, Lee, and Lo (2002), case study in China by Chiou, Hsu, and Hwang (2008) and Yan (2009), in Taiwan by Lee, Kang, Hsu, and Hung (2009) and Y. H. Chen and Chao (2012), and the study in Malaysia by Bhattacharya, Geraghty, and Young (2010). Nevertheless, there appears to be no case study formulating critical criteria and developing method for supplier selection decision in Thailand.

Many researchers have been dealing with supplier selection problem for decades. There are several methods to tackle with this problem. With multiple criteria of supplier selection, a fashionable method is comparing importance of criteria assuming that criteria are independent. Then calculate preference score of each potential supplier without consideration of uncertainties of supplier performance, especially if the data of performance throughout a periodic of time is not utterly symmetric, i.e. normal distribution. Therefore, for better reflect to real circumstances, this research attempts to develop a proper method to select supplier for Thai electronics manufacturers based on mean-variance-skewness of supplier's performance regarding multiple interrelated criteria by using ANP approach.

1.2 Problem Statement

Generally, when selecting supplier, buying firm should select the one which have high expected performance (i.e., mean) and low risk (i.e., variance). But consideration only mean and variance may not sufficient as mention earlier because literally supplier's performance could be fluctuated for a period of time. That is to say

that supplier whose performance has no skewness does not point out that it is good supplier.

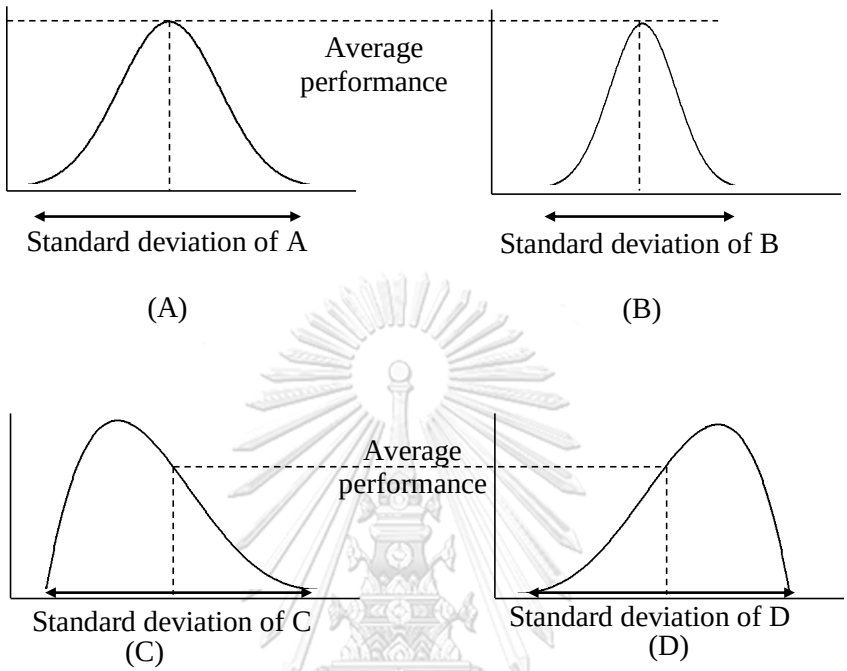


Figure 1.3 Example of on-time delivery performance of possible supplier A-D

For example, in order to evaluate supplier performance based on deliverability which is measured by %on-time delivery. Supposed that each graph in Figure 1.3 represents on-time delivery performance of different supplier (A-D). To compare between A and B, both of them has same average %on-time delivery, as mean of these two suppliers are equal. But the variance of A is greater than B as we can see that graph A is more spread out than B. In this case we can say that supplier B is better than A even though their average performances are equal since B's performance is more stable or has lower variance. In other words, lower SD means lower risk. But to compare between C and D, both suppliers has equal mean and SD. If buyer only takes mean and variance into account, then buyer may conclude that both of them have equal performance. But if buyer also takes skewness into consideration, despite the fact that C and D has equal average, both may perform different performance. Figure (C) shows that its performance skews to the right (positive-skew) while (D) skews to the left

(negative-skew). This means that most likely C has lower %on-time delivery than expected while D has higher since D's mode exceeds means and vice versa for C. Assuredly, buyers prefer left-skewed %on-time delivery to either right-skewed or symmetrical of %on-time delivery distribution. The question is, whether skewness has effect and plays important role on supplier performance.

Please be noted that there is 2 types of performance. One is performance with negative skewness is preferred or the higher of performance index, the better efficiency, such as %on-time delivery. Conversely, another one is performance with positive skewness is preferred or the lower of performance index, the better efficiency, such as cost and lead time. In this case buyers would prefer right-skewed rather than left-skewed performance.

Even there is an evaluating performance combines these 3 combinations together which is called mean-variance-skewness framework and often used in portfolio selection problem. In the problem of portfolio selection, the investor must select the optimal portfolio. To evaluate or measure portfolio performance, there is a method to evaluate based on mean-variance-skewness framework. The results prove that the efficiency obtained from combining those three moments is better than traditional evaluation. But in logistics research, no one ever applied this concept on supplier selection problem. This research aims to fill these gaps by developing decision matrices for selecting proper supplier with multiple interrelated criteria based on mean-variance-skewness of supplier's performance to enhance higher purchasing efficiency of buying firm.

1.3 Research Questions

From problem statement as explained in previous section, there are 2 research questions as follows:

1. Do the skewness has effect on performance?

2. If the answer is yes, should decision maker considers skewness on top of the average and standard deviation when selecting supplier and what is the proper method?

1.4 Research Objectives

1. To identify influential criteria and their important weight of supplier selection problem for Thai electronics industry.

2. To develop decision matrices for selecting supplier based on mean-variance-skewness of supplier's performance.

1.5 Research Methodology

After formulating criteria set which is gathered by literature review, then the questionnaire is designed in order to collect the data which has 2 types. The first type of data is the comparison among criteria to identify criteria important weight. This data will be analyzed using ANP approach. Another type is the data of performance evaluating in order to obtain the value of supplier performance in 3 characteristics, which is mean, standard deviation, and skewness. Then this data will be analyzed to explore skewness effect. Finally both type of data will be combined together in order to develop decision matrix.

1.6 Contribution

The main contribution of this research has two-folds. One is contribution for Thailand industry and another one is contribution for academic. For Thailand industry's contribution, this research will provide the appropriate systematic to help electronics industry in Thailand select the most suitable supplier in a practical way. For academic contribution, this research is the first one applying the concept of performance evaluation based on mean-variance-skewness framework on supplier selection problem and explore the importance of criteria of green supplier to enhance supply chain management sustainability.

CHAPTER 2
LITERATURE REVIEW

The main objective in this research is to develop decision matrices for selecting appropriate supplier with multiple interrelated criteria under risk consideration in order to enhance logistics efficiency of Thai electronics industry. This chapter will present related previous study including theory and principle that will be applied in this research. In order to achieve research objectives, literature review in this research is classified into 5 main topics.

1. Supplier selection criteria to extract influential criteria and construct initial set of criteria used in this research.

2. Supplier selection method to study methods that researchers used in supplier selection problem in order to identify suitable method for this research.

3. AHP and ANP approach which is the approach used in this research.

4. Performance evaluating to show the idea of skewness impact on supplier selection and the idea of bringing skewness into performance evaluation.

5. FMEA concept which is the measurement of potential failure in order to acquire the idea of new method for supplier selection.

2.1 Supplier Selection Criteria

In logistics and supply chain management, one of the key activities is procurement and purchasing activity. It is impossible to process all activities in order to manufacture products to end-customer in one place or one company. In reality businesses have been more relied on suppliers (Simić, Kovačević, Svirčević, & Simić, 2017). One of the important question on supplier selection problem is what are the critical criteria affecting to the decision process and how to measure the importance level of each criterion. Back to 1966, Dickson introduced 23 critical factors which affecting vendor selection and evaluation by spreading out questionnaire to purchasing agents and managers in United States and Canada. Among these 23 criteria, Dickson's survey revealed that the top 6 important criteria were quality, delivery, performance

history, warranties and claim policies, production facilities and capacity, and price, respectively. Notwithstanding that this study was published since 1966, some of criteria are still valid and considered as affecting factor on supplier selection by many researchers. After Dickson's study in 1966, Weber, Current, and Benton (1991) conducted research and reviewed about criteria and methods which had been studied by researchers since 1966-1990. From his review, it was found that price, quality and delivery were extremely influent to select a proper supplier. The next ranks are production facilities and capacity, geographical location, and technical capability, respectively. The different weight could come from changing of business and manufacturing environment. Table 2.1 shows comparison of ranking of criteria between Dickson (1966) and Weber et al. (1991).

Table 2.1 Criteria ranking between Dickson (1966) and Weber et al (1991)

No.	Criteria	Dickson's rank	Weber et al.'s rank
1	Quality	1	3
2	Delivery	2	2
3	Performance history	3	9
4	Warranties and claim policies	4	23
5	Production facilities and capacity	5	4
6	Price	6	1
7	Technical capability	7	6
8	Financial position	8	9
9	Procedural compliance	9	15
10	Communication system	10	15
11	Reputation and position in industry	11	8
12	Desire for business	12	21
13	Management and organization	13	7
14	Operating controls	14	13
15	Repair service	15	9
16	Attitude	16	12
17	Impression	17	15
18	Packaging ability	18	13
19	Labor relations record	19	15
20	Geographical location	20	5
21	Amount of past business	21	21
22	Training aids	22	15
23	Reciprocal arrangements	23	15

Since 1990s, many researches have been using Dickson's criteria to evaluate supplier. Apparently, cost, quality and delivery are the basic criteria that most of the studies considered. For example, Weber and Desai (1996) tried to measure supplier performance and efficiency based on combination of three basic performances required criteria, namely cost, quality, and delivery. De Boer, Van Der Wegen, and Telgen (1998)also considered cost and quality as major criteria that buying firm should concerned but location of supplier and supplier's yearly turnover were added in to the decision model. The reason was in JIT production system; supplier should not be located too far from manufacturing firm and should not too small or too big for buying firm to manage. Verma and Pullman (1998) did research about how managers choose suppliers and trade-off among four influential criteria, which are cost, quality, delivery, and flexibility. By surveying from questionnaire sent to 139 metallic tooling manufacturers in Western United States, it was found that quality is the most important criteria, followed by on-time delivery, cost, lead time and flexibility, respectively. Similar to Verma and Pullman's study, Albino and Garavelli (1998) considered cost, quality, and delivery as basic performances with management skill of supplier and technical capability when making decision while Ghodsypour and O'Brien (1998) and Ghodsypour and O'Brien (2001) included production facilities and capacity to be one of their criteria.

Under the assumption of product quality among alternate suppliers are identical, Cakravastia, Toha, and Nakamura (2002) selected cost and on time delivery to be critical factors as they implied in their study that to satisfy end customers is comprised of price and lead time. Choy et al. (2002) used the case-based reasoning (CBR) and neural network (Kannan & Tan) approaches to evaluate and select supplier into 2 stages. First is to retrieve potential supplier lists then benchmarking suppliers in the list to select the best one among potential suppliers. Five criteria were considered in the final decision. Four of them were taken from Dickson' criteria, namely, cost, quality, delivery, and supplier financial. Also one additional criterion, customer service, was added other than Dickson's. Katsikeas, Paparoidamis, and Katsikea (2004) did the study to examine supplier performance based on buying decision criteria of cost, quality, delivery, technical capability, procedural compliance. Also this is one of few studies which brought criteria of warranties and claim policies back to decision model.

It is noticed that lately, in researches on supplier selection problem, number of critical criteria taken into account has been increasing with more complex decision structure. For example, other than consideration of basic criteria, Gencer and Gürpinar (2007) also considered other critical factor when developing decision model to select supplier in an electronics company. Totally, 12 criteria from Dickson's study had been taken into account. Bhattacharya et al. (2010) selected 9 criteria from Dickson 23 criteria to be considered same as Xiao, Chen, and Li (2012) but different criteria were concerned. The criteria of each study are shown in Table 2.2, as well as other researches that are mentioned above.

Moreover, since the 21st century has been started, the concerning of green logistics and supply chain management has been growing. Some of researchers have brought green issue to be one of critical factor when making selecting supplier. For example, Li and Zhao (2009), Yan (2009), Mafakheri, Breton, and Ghoniem (2011), Y. H. Chen and Chao (2012), included greenness criteria into their decision model. Chiou et al. (2008), compared ranking of critical criteria including green concerning among American, Japanese and Taiwanese Electronics Industry in China. The result showed that all 3 basic performances, cost, quality, and delivery still had importance more than greenness of supplier. Similar to the study of Lee et al. (2009), this study implied that buying firms preferred criteria which related to their efficiency such as cost, quality, delivery, and technical capability rather criteria of being green supplier. However, environmental issue has been continuously increasing its importance. Thus, a green supplier criterion is considered as one of critical criteria in this research.

Apparently supplier selection is multi-criteria decision making. Also not only quantitative criteria should buying firm consider but also qualitative criteria Ghodsypour and O'Brien (1998). Selecting a suitable supplier is trading off among those influential factors. Table 2.2 shows influential criteria on supplier selection problem used in previous researches. It should be noted that some criteria are renamed to match with Dickson's criteria depending on its definition.

Table 2.2 Summary of supplier selection criteria in previous studies

No.	Authors	Dickson's criteria																					Additional criteria			
		Cost	Quality	Delivery	Warranties and claim policies	Procedural compliance	Repair service	Management and organization	Impression	Communication system	Labor relations record	Amount of pass business	Reciprocal arrangements	Performance history	Financial position	Desire for business	Reputation and position in industry	Production facilities and capability	Attitude	Geographical location	Operating controls	Training aids	Technical capability	Packaging ability	Flexibility	Relationship	Service ability	Green supplier
1	* Dickson (1996)	1	1	1	1									1				1										
2	Weber et al. (1991)*	1	1	1														1		1			1					
3	Weber (1996)	1	1	1																								
4	Weber & Desai (1996)	1	1	1																								
5	Albino &Garavelli (1998)	1	1	1				1															1					
6	De Boer et al. (1998)	1	1												1					1								
7	Verman&Pullman (1998)	1	1	1																					1			
8	Ghodsypour&O'Brien (1998)	1	1	1														1										
9	Jian et al. (2000)	1	1	1														1		1								

		No.	10	11	12	13	14	15	16	17	18
		Authors	Ghodsypour & O'Brien (2001)	Cakravastia et al. (2002)	Choy et al. (2002)	Katsikeas et al. (2004)	Gencer& Gurpina (2007)	Chiou et al. (2008)	Lee et al. (2009)	Li & Zhao (2009)	Yan (2009)
Dickson's criteria		Cost	1	1	1	1		1	1		1
		Quality	1		1	1	1	1	1	1	1
		Delivery	1	1	1	1	1	1	1		1
		Warranties and claim policies				1					
		Procedural compliance				1					
		Repair service									
		Management and organization					1		1	1	
		Impression									
		Communication system					1			1	1
		Labor relations record									
		Amount of pass business									
		Reciprocal arrangements									
		Performance history									
		Financial position			1		1		1		
		Desire for business									
		Reputation and position in industry								1	
		Production facilities and capability	1				1				1
		Attitude							1		
		Geographical location					1			1	
		Operating controls					1				
		Training aids					1				
		Technical capability				1	1		1	1	
		Packaging ability					1				
Additional criteria		Flexibility							1		
		Relationship								1	
		Service ability			1		1	1		1	1
		Green supplier						1	1	1	1

		No.	19	20	21	22	23	24	25
		Authors	Bhattacharya et al. (2010)	Aksoy & Ozturk (2011)	Mafakheri et al. (2011)	Y.H. Chen & Chao (2012)	Xiao et al. (2012)	P-S. Chen & Wu (2013)	Dargi et al. (2014)
Dickson's criteria		Cost		1	1	1		1	1
		Quality	1	1	1	1	1	1	1
		Delivery	1	1	1	1	1	1	1
		Warranties and claim policies						1	
		Procedural compliance	1					1	
		Repair service							
		Management and organization	1			1			
		Impression							
		Communication system					1		
		Labor relations record							
		Amount of pass business							
		Reciprocal arrangements							
		Performance history					1		
		Financial position	1			1	1		
		Desire for business							
		Reputation and position in industry	1						1
		Production facilities and capability				1	1	1	1
		Attitude	1						
		Geographical location		1					1
		Operating controls							
		Training aids					1		
		Technical capability	1			1	1	1	1
		Packaging ability							
Additional criteria		Flexibility	1			1		1	
		Relationship				1	1		
		Service ability							1
		Green supplier			1				

From 25 papers, the summary of criteria used are shown in Table 2.3. In first column, “D” and “+” refers to Dickson’s criteria or additional criteria besides Dickson’s.

Table 2.3 Summary of criteria frequency used

D/+	Criteria	% of used
D	Quality	96
D	Delivery	92
D	Cost	84
D	Production facilities and capacity	44
D	Technical capability	44
D	Financial position	28
D	Geographical location	28
D	Management and organization	24
+	Service ability	24
+	Flexibility	20
+	Green supplier	20
D	Communication system	16
D	Warranties and claim policies	12
D	Procedural compliance	12

D/+	Criteria	% of used
D	Reputation and position in industry	12
+	Relationship	12
D	Performance history	8
D	Attitude	8
D	Training aids	8
D	Operating controls	4
D	Packaging ability	4
D	Repair service	0
D	Impression	0
D	Labor relations record	0
D	Amount of past business	0
D	Reciprocal arrangements	0
D	Desire for business	0

The summary of frequency used in Table 2.3 is used as the guideline to formulate the initial set of criteria in this research. Which will be explained later in Chapter 3.

2.2 Supplier Selection Method

Based on research methodology, after formulating criteria has been done, the next issue to be determined is what is the proper supplier selection method should be used in this research. From study of De Boer et al. (2001) supplier selection processes were classified into 4 phases as shown in Figure 2.1. First is to define the problem, what exactly the aim of problem is and what a firm wants to achieve. Then formulate set of critical criteria before qualifying process of suitable suppliers to obtain a set of potential suppliers. In other words, pre-select suppliers to reduce number of possible suppliers. Then make the final decision and select the most appropriate supplier.

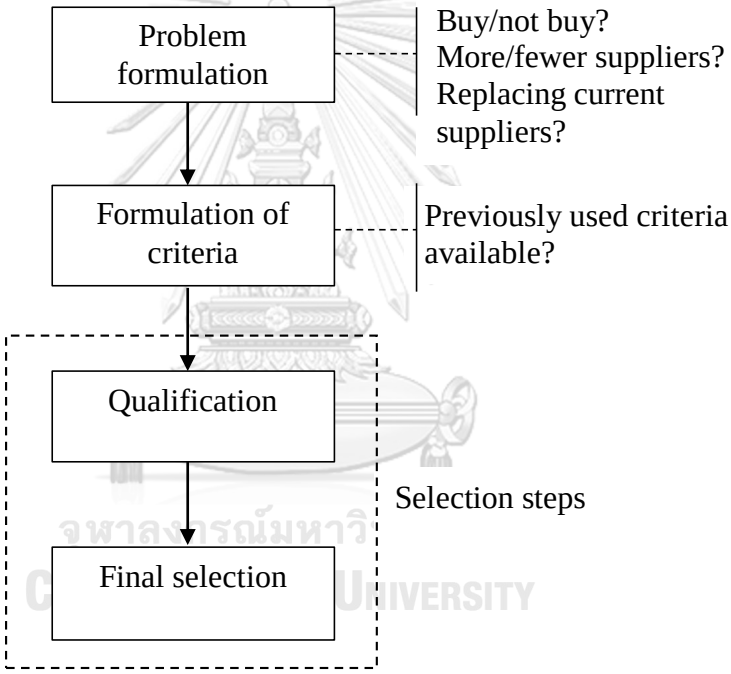


Figure 2.1 Decision methods in supplier selection processes (modified from De Boer et al. (2001))

From these processes, it indicates that in there are two steps of selection, one is pre-selection and another one is final selection. Therefore, this topic is separated into 2 sections. First section is method to pre-qualify supplier. The second one is method to make final selection.

2.2.1 Method of Supplier's Pre-qualification Phase

As mention in previous paragraph, pre-qualification phase or pre-selection phase is the process to reduce number of potential suppliers before making final decision. So the idea of this phase is mainly classification suppliers into groups. Then the decision maker can select group of suppliers that has highest potential than other groups. From literature review, it is found that there are 4 decision methods dealing with pre-selection step, i.e. categorical methods, data envelopment analysis (DEA), cluster analysis (CA), and case based reasoning (CBR).

- Categorical Method

Categorical method is a method to evaluate supplier's performance by categorical judging from decision maker. The buying firm evaluates each alternate supplier's performance on each criteria as either, good (positive), moderate (neutral) or inefficient (negative), then summarize the overall rating (Timmerman, 1986). The shortcoming of this method is all criteria are assumed to have same important weight that is reflect to real decision making.

- Cluster Analysis (CA)

The next method is cluster analysis (CA). CA is the statistical classification technique to divide data into groups or clusters. A research by Holt (1998) applied this approach to supplier selection problem. In supplier selection problem, data is the whole list of suppliers. By classifying suppliers based on their performance, all suppliers are allowed to be separated into groups or clusters. The variance of performance within clusters is small or homogeneous but variance between clusters is large or heterogeneous. Generally we can say that suppliers in the same cluster have similar performance whereas suppliers in different clusters have different performance. Then, buying firm is able to select cluster or group of supplier which has higher performance compared with other groups to be potential suppliers. Therefore, the numbers of potential suppliers are reduced. This method is well pre-qualifying suppliers.

- Data Envelopment Analysis (DEA)

One of the well-known methods to pre-select suppliers is data envelopment analysis (DEA). DEA is the technique used to compare performance efficiency of decision making units (DMUs) developed by Charnes et al. (1978). In DEA technique, all DMUs are evaluated its output efficiency based on its input and classified into two groups which judging by efficiency score of each. The maximum efficiency score is equal to one, and the DMUs with maximum efficiency score is call efficient DMUs. Another one is considered as inefficient DMUs which have efficiency score less than one.

For supplier selection problem, each DMU refers to each supplier. Applying this technique, buying firms are able to distinguish between potential suppliers and incompetent suppliers that are efficient suppliers and inefficient suppliers, respectively. There are several researches applying DEA to supplier selection problem. For example, Weber and Desai (1996), based on three criteria of price (i.e. cost), quality, and delivery, the authors applied DEA to measure supplier's performance and efficiency. In this study, there are totally six suppliers to evaluate. One of the benefit of DEA is this technique is not only be able to evaluate the performance of each supplier but also helps inefficient vendors to perceive their own relative performances benchmark with efficient suppliers (Weber, 1996). Other studies of DEA in supplier selection can be seen in Jian, Fong - Yuen, and Vinod (2000), Toloo and Nalchigar (2011) and Dobos and Vörösmarty (2014).

- Case Base Reasoning (CBR)

The last method used for supplier pre-selection phase is case based reasoning (CBR). Choy et al. (2002) applied this method on supplier pre-qualification stage to regain list of candidate suppliers before benchmarking candidate suppliers and finalize who should be selected by using neural network engine (NNE). This method is used artificial intelligence (AI) technique to solve the problem by using previous similar situations, information, and knowledge in a huge database. But the shortcoming of this method is it requires enormous database.

2.2.2 Method of Supplier's Final Decision Phase

The final decision phase is the stage to select the most suitable supplier. This stage can be done either after finishing pre-quality stage or after getting the whole list of suppliers, i.e. supplier pre-qualification is omitted. There are several methods to make final choice in supplier selection problem as follows:

- Mathematical Optimization

In this approach, the decision makers formulate mathematical model based on the set of constraints to optimize objective function which could be maximization (e.g. maximizing profit) or minimization (e.g. minimizing cost or lead time of purchasing). This method could be more objective and quantitative than rating method De Boer et al. (2001). Weber and Current (1993) proposed multi objective optimization model for vendor selection. Three objectives were included in their model, which are to minimize purchasing price (i.e. cost criteria), to minimize late deliver by vendor (i.e. delivery criteria), and to minimize rejected units (i.e. quality criteria). In the study of Ghodsypour and O'Brien (2001), not only considering net price of purchasing but this paper also proposed to select supplier with the objective of minimizing total cost of logistics, that are, net price, ordering cost, transportation cost and holding cost. Liao and Rittscher (2007) stated that flexibility provided by suppliers to arrange their processes and conditions is important. Therefore with multi objectives comprised of cost minimization, quality rejection rate minimization, late delivery minimization and flexibility maximization, together with constraints of customer demand, supplier's capacity the authors formulated model to select supplier.

There are some researcher combines mathematical optimization methods with other approaches, for example, Mafakheri et al. (2011). In this paper, two types of cost, purchasing cost and inventory holding cost which related to quantities ordered, were considered as objective functions. Considering time varying of purchasing cost and inventory holding cost, dynamic function of those bi-objectives were formulated.

However, the characteristics of supplier selection problem are hard to formulate mathematical model Weber and Current (1993). So the great disadvantage of this

technique is with the greater number of variables of factors, the more complex and harder to solve the problem.

- Artificial Intelligence (AI) and Neural Network (Kannan & Tan)

Artificial Intelligence (AI) is computer science to simulate human intelligence by training computers to understand human's intellect to compute or to solve the problem in terms of achieving the goal. It is like imitating human reaction based on historical data or previous experience. One of method based on AI that researchers used to solve supplier selection problem is neural network (Kannan & Tan). In NN method, it is not necessary to formalize the process of decision making and this is well reflect to real situation as NN can cope with uncertainty and complication De Boer et al. (2001). Albino and Garavelli (1998) propose NN to evaluate subcontractors in construction firms. With set of input parameter, i.e. selection criteria, the network is trained by the examples of training set. Once the training process is done, the network is tested accuracy. Finally by giving a real data set of competitors, i.e. potential suppliers, the network can evaluate potential suppliers and provide final competitor rating to decision maker.

Choy et al. (2002) applied CBR technique and NN to select and benchmark suppliers for case study of consumer product companies in Hong Kong. Case base reasoning technique is used in pre-selection stage as mentioned in previous section, and then NN is used to finalize the decision. Another study that presented NN approach to supplier selection problem is done by Aksoy and Öztürk (2011). To overcome the drawback of traditional selection and evaluation approaches, that are the complexity of decision process with multiple attributes and the uncertainties, the authors introduced NN approach to support supplier selection process focusing on just-in-time (JIT) manufacturers based on four criteria, which are quality, delivery, location of supplier, and price. As stated earlier, the advantage of NN is this approach does not need decision making process formulation and well handle uncertain and complicated situation. However, NN requires enormous database. Also the process between input and output layer is like a black box and hard to trained the network.

- Multi Criteria Decision Making (MCDM) Technique

It is no doubt that supplier selection is multi-criteria decision making problem. Many MCDM techniques have been used to tackle with this decision problem. For example, analytic hierarchy process (AHP), analytic network process (Eshtehardian, Ghodousi, & Bejanpour), and fuzzy theory.

In AHP and ANP approaches, all criteria are weighed and alternatives are ranked based on pairwise comparison. These approaches are able to deal with both of quantitative and qualitative criteria and simplify complex problem into hierarchical form. For example, Ghodsypour and O'Brien (1998) applied AHP technique to determine important weight of criteria as well as overall score of alternate suppliers. Li and Zhao (2009) used AHP to select the most suitable for automotive industry. Similar to Chen and Wu's study in 2013, but this research applied AHP technique to select supplier for semiconductor manufacturer. Although AHP is a well-known method but it has some shortcoming as in AHP, the relationship among criteria are ignored and assumed to be independent. Consequently, some researchers try to overcome this shortcoming by applying ANP approach, for example, the study of Gencer and Gürpinar (2007) and Xiao et al. (2012).

In traditional AHP and ANP, the decision makers make pairwise comparison by giving the exact number of preference but in reality, human preference is hard to attain. For this reason, fuzzy theory has brought into MCDM technique. Chiou et al. (2008) proposed fuzzy analytic hierarchy process (FAHP) for case study of overseas electronics industry in China. After collecting pairwise comparisons from decision maker, the result are transformed in to fuzzy number using triangular fuzzy number. Lee et al. (2009) also applied fuzzy set theory using fuzzy extended AHP (FEAHP) which is the method carried out by triangular fuzzy numbers then uses extend analysis method to determine value of pairwise comparison. This research is applied on the case study of LCD industry in Taiwan. Fuzzy theory is not only applied on AHP but also ANP as well. Dargi, Anjomshoae, Galankashi, Memari, and Tap (2014) used fuzzy ANP (FANP) to determine the important weight of criteria and applied this method on the case study of Iranian automotive company.

- Hybrid method

To develop the better accurate method dealing with supplier selection problem, some researches combine more than one approach together. Ghodsypour and O'Brien (1998) combined AHP and linear programming (LP) on two-stage supplier selection problem. First AHP was used to determine rating of each alternate supplier. Then, LP optimization was used to find the best supplier and its order quantity aimed to maximize total value of purchasing. Yan (2009) implemented hybrid method combining AHP and genetic algorithm (GA) to better calculate weight score and rank the alternate suppliers. Bhattacharya et al. (2010) conducted a research by combining AHP and quality function deployment (QFD). QFD is the tool to let a firm knows customer's needs and expectation, i.e. voice of customer. Firstly, all criteria are classified into 2 groups. One is criteria related to customer requirement, such as delivery, quality, etc. Another group is criteria related to engineering requirement, such as company's infrastructure and facility. After developing QFD matrix, important weights of criteria obtain from QFD matrix are used as the pairwise comparison to calculate utility value (priority vector in AHP). Then a decision maker can rank the alternate suppliers and select the most suitable one.

Furthermore, there are other hybrid methods, for example, the combination of DEA, decision tree and NN presented by Wu (2009)

- Other methods

In addition above approaches, there are other methods proposed by researchers. For example, Verma and Pullman (1998) explored important level of supplier selection criteria, cost, quality, delivery, and flexibility by surveying using linker scale questionnaire. Then used discrete choice regression analysis to acquire weight (i.e. regression coefficient).

Table 2.4 Summary of supplier selection methods

Technique	Methodology	Authors
Pre-qualification phase		
Categorical method	It uses categorical judging from decision maker for evaluating each alternate supplier's performance on each criterion, and then summarizes the overall rating.	Timmerman (1986)
CA	CA is statistical classification technique to suppliers into groups or clusters, aiming to reduce the number of potential suppliers.	Holt (1998)
DEA	It is mathematical programming technique to evaluate performance efficiency of suppliers based on its multiple inputs and multiple outputs and classified into two groups, sufficient and insufficient suppliers.	Weber (1996), (Weber & Desai, 1996) Jian et al. (2000), Toloo and Nalchigar (2011), Dobos and Vörösmarty (2014).
CBR	CBR uses artificial intelligence (AI) technique to solve the problem by inputting database of previous similar situations, information, and knowledge.	Choy et al. (2002)
Final decision phase		
AI & NN	It is computer science to simulate human intelligence by training computers to understand human's intellect to compute or to solve the problem in terms of achieving the goal but it needs a huge database.	Albino & Garavelli (1998), Choy et al. (2002), Aksoy and Ozturk (2011)
Optimization	This method is based on mathematical programming to optimize result which including single objective or multi-objective. The disadvantage of this technique is with the greater number of variables of factors, the more complex and harder to solve the problem.	Weber and Current (1993), Liao and Rittscher (2007), Mafakheri et al. (2011).

Technique	Methodology	Authors
Final decision phase		
MCDM techniques	MCDM techniques are the techniques to help decision maker to make decision based on multiple criteria with different weight importance.	Ghodsypour & O'brien (1996), Gencer & Gurpina (2007), Chiou et al. (2008), Lee et al. (2009), Li & Zhao (2009), Xiao et al. (2012), Chen & Wu (2013), Dargi et al. (2014)
Hybrid method	It is the combination of more-than-one approach to solve problem of supplier selection to gain better efficiency.	Ghodsypour & O'brien (1998). Yan (2009), Bhattacharya et al. (2010), Wu (2009).
Others	For example, regression analysis	Verma & Pullman (1998)

2.2.3 Selection Method Comparison

As mention earlier that there are 2 decision phases in supplier selection, which are, pre-qualification phase and final decision phase. From literature review, it is found that some methods are well used in decision phase of pre-qualification which is the decision to distinguish between potential suppliers and non-potential suppliers. But among potential suppliers, it is necessary to use other method in order to decide of who is the most suitable suppliers. The pros and the cons of each method are summarized and shown in Table 2.5 and Figure 2.2.

Table 2.5 Comparison among selecting method

Method	Phase	Pros	Cons
Categorical method	Finalize	• Very easy and simple concept • Be able to deal with both of qualitative and quantitative criteria	• Very subjective and hard to judge • Every criteria are assumed to have same level of preference.
Cluster Analysis	Pre-qualify	• Able to deal with large number of suppliers. • Can reduces the probability to reject 'good' supplier too early in the process via subjective • It is wildly used statically method so its concept is not new and too complex, and also it is familiar to most statistical software	• Can only separate potential suppliers from all alternative suppliers but not give the answer of the best supplier.
DEA	Pre-qualify	• Provide the guidance of how inefficient suppliers need to improve themselves to become efficient suppliers.	• Normally used for quantitative criteria. • Can only separate potential suppliers from all alternative suppliers but not give the answer of the best supplier.
CBR	Pre-qualify	• Very flexible and better-reflect real world situation as it uses AI technique. • Be able to deal with both of qualitative and quantitative criteria.	• Need enormous database. • Very complex but can only separate between potential and non-potential suppliers.
AHP ANP Fuzzy	Finalize	• Be able to deal with both of qualitative and quantitative criteria.	• It is subjective method which depends on the judgment of decision makers.
Math Model	Finalize	• The answer is optimization. • Less conflict.	• Normally used for quantitative criteria. • Hard to formulate the model and not flexible in the real life.
NN	Finalize	• Well handle uncertain and complicated situation.	• Very complicated and needs a huge database.

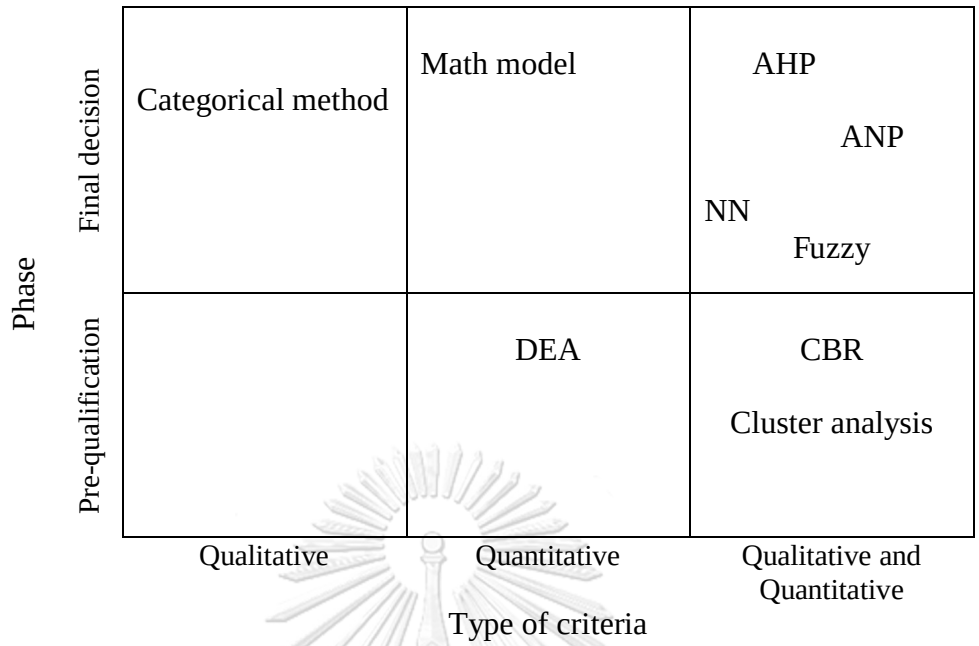


Figure 2.2 Comparison of supplier selection method

From pros and cons of each method summarized in Table 2.5, the comparison is illustrated in Figure 2.2. The comparison is based on 2 dimensions. First dimension is decision phase. This research is aimed to develop decision matrix to select the most proper suitable supplier, therefore only methods able to deal with final decision can be selected. The second dimension is criteria type. Some methods well-deals with either quantitative or qualitative criteria. But the set of criteria in this research comprises of both qualitative and quantitative criteria, therefore the possible methods are AHP, ANP, Fuzzy theory, and NN. But to simplify method but still consider dependency among criteria, this research will use ANP as being selection method.

2.3 Analytic Hierarchy Process (AHP) and Analytic Network Process

As explained in the previous section, ANP is selected as a tool to determine weight of criteria on supplier selection problem. Therefore, this section explains about the principle and fundamental concept of this approach. ANP approach is built on the concept of AHP method to fill the limitation of traditional AHP that criteria are assumed to be independent. To explain about ANP, it is necessary to explain about AHP first. Therefore, literature review in this topic is separated into two parts. First is about AHP, and the next part is about ANP.

2.3.1 Analytic Hierarchy Process (AHP)

In multiple criteria decision making (MCDM) problem, there are many approaches to deal with this kind of problem. One of the most widely used approach is AHP which is the method introduced by Saaty in 1980. AHP is a useful method helping decision maker to prioritize alternatives or potential suppliers with multiple criteria. The core of AHP approach is hierarchical decision model structuring. Starting with the objective (i.e. goal) as the first or top level, based on multiple criteria in lower level which can separate into sub-criteria if needed, and alternatives at the bottom level, as shown in Figure 2.3.

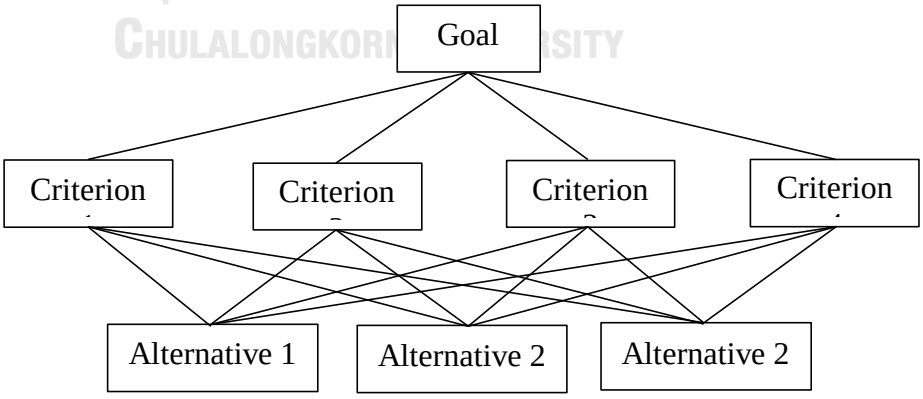


Figure 2.3 AHP hierarchical decision model

The basic concept of AHP is to obtain important weight of each criteria, then calculate score of each alternative based on all criteria and rank the alternatives. The comparison of importance among criteria and preference among alternatives uses pairwise comparison. The steps of AHP can summarized into 5 steps as follows:

1. Construct the decision hierarchy model (i.e. decision tree). After identifying goal of problem at the top level, affecting factor or criteria must be determined. Then construct the hierarchical decision structure.
2. Make pairwise comparisons of criteria and alternatives in the same level.
3. Check the consistency of pairwise judgment and re-do step 2 if needed (i.e. consistency ratio: CR is greater than acceptable interval).
4. Convert result from pairwise comparisons into important weights.
5. Calculate total score of each alternative and rank the alternatives.

To make pairwise comparisons, the decision maker is required to give preference number to compare between two items. Normally, the scale of preference (i.e. intensity of importance) is rated from 1 to 9. The definitions of all numbers are shown in Table 2.6.

Table 2.6 The fundamental scale for pairwise comparisons (Saaty, 1980, 2008)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the goal
2	Weak or slight	
3	Moderate importance	The decision maker slightly prefer one factor to another
4	Moderate plus	
5	Strong importance	The decision maker strongly prefer one factor to another
6	Strong plus	

Intensity of Importance	Definition	Explanation
7	Very strong or demonstrated importance	The decision maker very strongly prefer one factor to another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one factor over another is of the highest possible order of affirmation
Reciprocals of above	When compare factor A with B, if above number is assigned, then the reciprocal value is given when compare B with A	

From the decision model structure in Figure 2.3, we can construct pairwise matrix of criteria as shown in Table 2.7.

Table 2.7 Example of pairwise matrix

	Criteria 1	Criteria 2	Criteria 3	Criteria 4
Criteria 1	1	2	5	2
Criteria 2	1/2	1	4	1/2
Criteria 3	1/5	1/4	1	1/4
Criteria 4	1/2	2	4	1

After pairwise comparisons are done, the consistency must be checked before calculating important weights as well as alternative scores. Then the consistency of pairwise judgement is investigated. This can be judged by consistency ration (CR) which is computed by following equation:

$$CR = \frac{CI}{RI} \tag{2.1}$$

$$CI = \frac{\lambda_{\max} - n}{n} \tag{2.2}$$

Where CR is consistency ratio

CI is consistency index

RI is random consistency index

λ_{max} is largest eigen value

n is number of elements in pairwise matrix (i.e. size of matrix)

From equation 2.1, CR is the ration between CI and RI. RI represents average consistency index obtained from randomly generated pairwise matrices of various size of matrix. Normally we accept that inconsistency should be not greater than 10%. In other words, the value of CI should be smaller or equal to 0.1. If CR of each pairwise matrix is acceptable, then the results are transformed into important weights and the total score of each alternative is calculated. The RI of various sizes of matrices is shown in Table 2.8.

Table 2.8 Random consistency index of various size of pairwise matrix

n	RI	n	RI	n	RI
1	0	6	1.25	11	1.51
2	0	7	1.35	12	1.54
3	0.52	8	1.4	13	1.56
4	0.89	9	1.45	14	1.57
5	1.11	10	1.49	15	1.58

2.3.2 Analytic Network Process

Although AHP is well-know and widely used among researchers but it seems to have a shortcoming that it cannot well reflect real case. In AHP we assumed that criteria are independent that is to say, no effect of one criterion on other criterion. But in real case, criteria are always have interrelation. For example, in supplier selection problem with cost and quality criteria. Obviously, buying firms prefer low cost and high quality but with lower cost, buying firm may accept lower quality if its quality still be acceptable. This implies that it may have interaction between clusters as well as

interaction between elements from different level. Thus, it is impossible to construct decision model in hierarchical structure. To overcome this shortcoming, decision model is construct and represented by network instead of hierarchical structure. This decision model is call analytical network or we could say that it is AHP with the assumption of criteria dependence between cluster and elements was developed, namely, analytic network process (Eshtehardian et al.) (Saaty, 1999).

From the network in Figure 2.4, criteria C_2 has dependence on C_1, C_3 and C_4. C_4 has dependence on C_1 and C_3, or it is easy to say that there are relationship between C_1 and C_4, and between C_3 and C_4. Also, on the other hand, C_3 has dependence on C_4. The loop arrow of each cluster represent the dependence among elements in that cluster. To make pairwise comparisons among these criteria, the network supermatrix as shown in Figure 2.5 is constructed.

In Figure 2.5, C_i represents cluster i and e_{ij} represents element j in cluster i. For example, e_{12} represent element 2 in cluster 1. And w_{ijk} represents weight component of element j in cluster i on j^{th} column. Finally, the result is transformed into important weight of criteria.

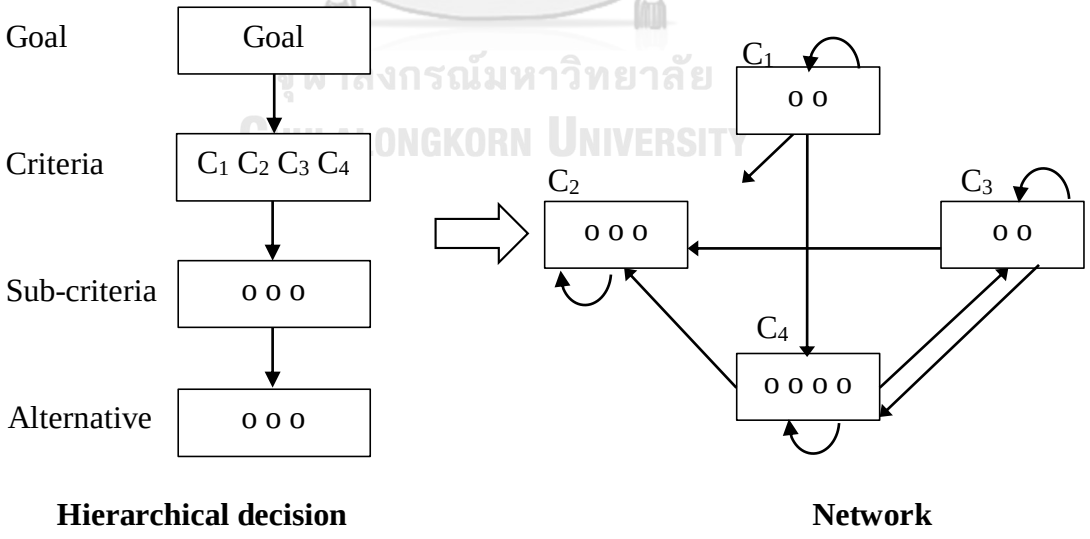


Figure 2.4 Transformation of hierarchical decision structure to network structure

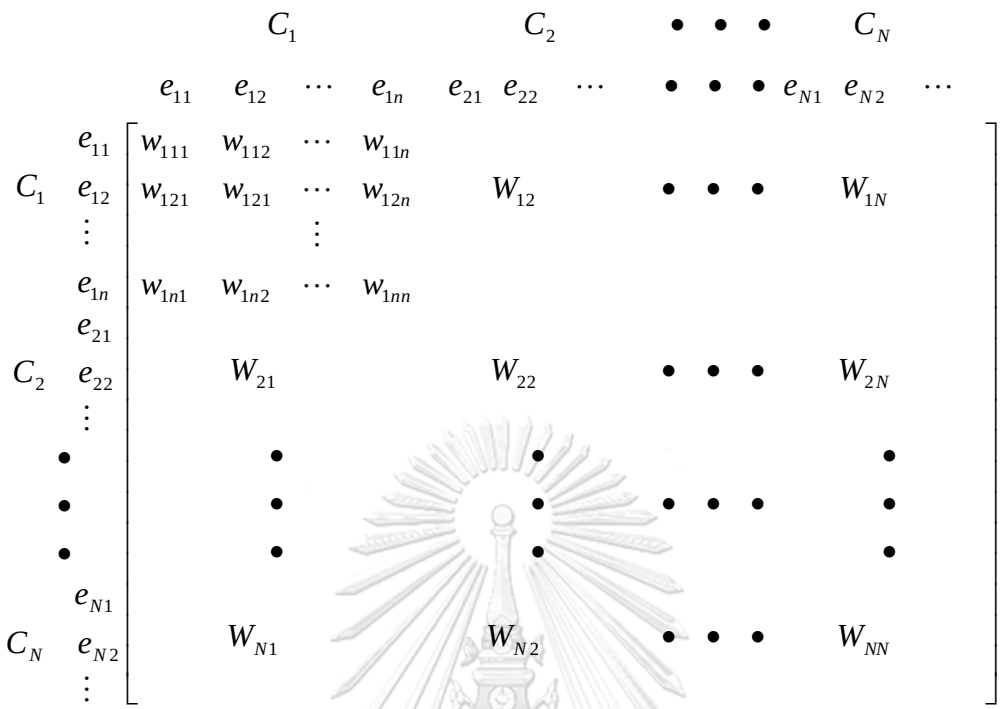


Figure 2.5 Supermatrix of a network

2.4 Performance Evaluating

2.4.1 Skewness Impact uncertainty in Supplier Performance

In statistics, the index providing information of quantitative measurement which is call moments. The first moment is the measurement of the location of central tendency. This moment is denoted by mean or average value. The second moment is the measurement of variability or the width around the first moment. This moment gives information of distribution spreading which is measured by variance or standard deviation. The third moment is the measurement which provides information of shape distribution. This moment is called skewness.

To apply above concept into supplier selection problem, supposed that we have a set of random variable X, a probability distribution of this random variable can be expressed in terms of moments of the distribution. As explanation in previous paragraph, there are several levels of moment. First moment represents mean or the expected value of X. The second moment is variance of X. The third and the forth moments are

skewness (i.e., measuring symmetry of probability distribution) and kurtosis (i.e., measuring flatness), respectively (Gujarati, 2003).

Supposed that random variable X representing supplier's performance. Then the expected value of supplier's performance, X, is expressed as E(X). Then the mean, variance and skewness of supplier's performance are defined as follows:

Mean; $\mu = E(X)$ (1)

Variance; $\sigma_X{}^2 = E(X-\mu)^2$ (2)

Skewness; $S_X = E(X-\mu)^3$ (3)

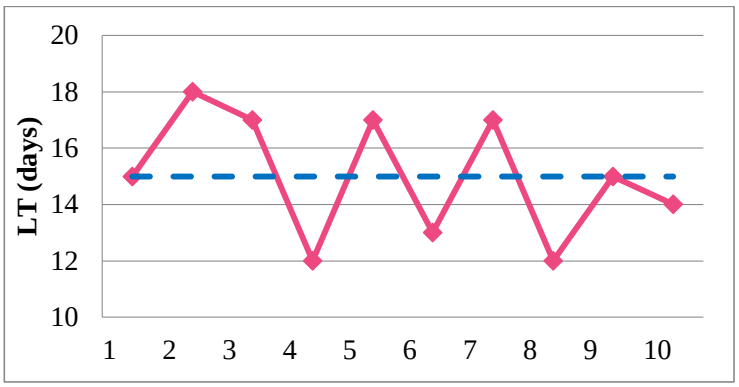
Where $E(X)$ is expected value of supplier's performance

μ is average of supplier's performance

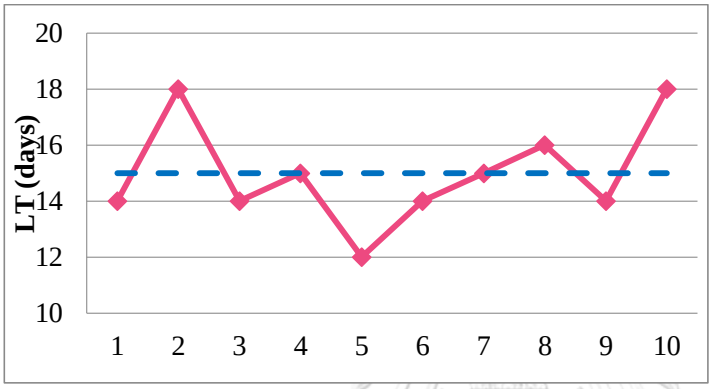
$\sigma_X{}^2$ is variance of supplier's performance

S_X is skewness of supplier's performance

For example, A company needs to buy raw materials from supplier and 2 options are available, which is buying from supplier A and buying from supplier B. Supposed that buyer merely concerns on lead time. The historical lead time of both suppliers are shown in following graphs.



Supplier A
- Average LT =15 days
- Max LT = 18 days
- Min LT = 12 days
- Mode = 17 days



Supplier B
- Average LT =15 days
- Max LT = 18 days
- Min LT = 12 days
- Mode = 14 days

Both of supplier A and B have equal average lead time of 15 days. Also there performance dispersions are approximately equal as their range are 6 days for both of them. If the decision maker select by judging from average performance and stability, it may be said that both of them have equal performance. But most likely, supplier A provides longer lead time than average as its mode is greater than average at about 17 days. In contrary, most likely supplier B can provide shorter lead time than average, as its mode is equal 14 days. Therefore, actually supplier B is performance better than supplier A, although their average lead time and standard deviation are equal. In this case, it suggests that their performance are not symmetrical shape. Performance of supplier A is skewed to right (greater than average) while performance of supplier B is skewed to the left (lower than average). The issue to be considered is if buyers should consider skewness when evaluate suppliers' performance.

2.4.2 Mean-Variance-Skewness Performance Evaluations

In financial and economic research, there is a problem of portfolio selection which the investor should make decision to select the optimal portfolio considering uncertainties in term of risk aversion. In process of selection, not only expected return should be considered because the portfolio with greatest expected return does not mean the most suitable one. That is to say the portfolio with the best expected return is not necessarily having minimum variance (Markowitz, 1952). Therefore, variance has been used widely for risk measure (Huang, 2012). To evaluate or measure portfolio performance, there are many researches on portfolio performance evaluation based on mean-variance-skewness framework. At the beginning, the researchers evaluate portfolio based on mean and variance and ignored skewness. The mean-variance model is introduced by Markowitz in 1952. Supposed that there are n possible choice of portfolio denoted by X_1, X_2,...,X_n. Let E_i is the expected return that the investors could get from each portfolio and V_i is the variance of each alternative. Figure 2.5 shows all set of (E, V) from all possible choices of portfolio. Each point represents expected return (mean) and risk (variance) of each portfolio. The border of the surface is called efficient surface or efficient frontier. The investors should select portfolios which fall on the border as they are denoted as efficient combinations. Additionally, based on mean-variance theory, the investors should select portfolios which give maximum expected return (E) for given variance (V) or less or those with minimum variance for given expected return (E) or more.

From explanation in previous paragraph, it is clearly that decision making in portfolio selection is trade-off between return (mean) and risk (variance) for all portfolio which fall on efficient frontier. Mean-variance model is extensively applied by many researchers, for example, Fletcher (1994), Chiu and Wong (2011), Castellano and Cerqueti (2014).

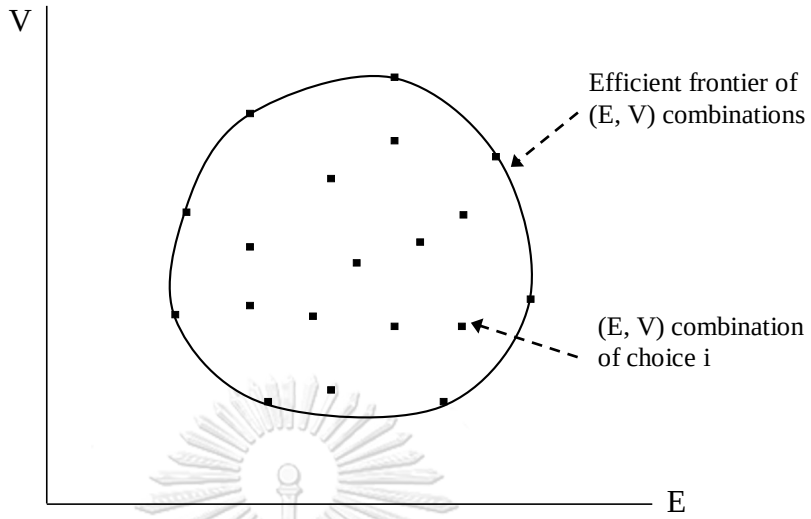
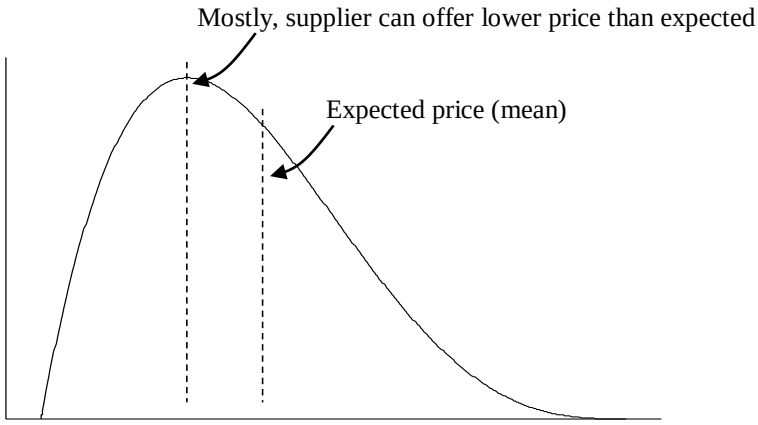


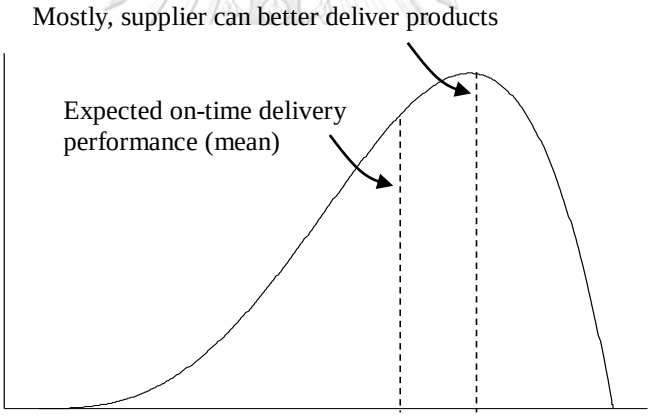
Figure 2.6 Combination of mean-variance of possible choice
(modified from Markowitz (1952))

Even though there are a vast study used mean-variance theory, but afterward, researchers found that the third moment should not be ignored then skewness was included to evaluate performance. Joro and Na (2006) developed portfolio performance measurement based on mean-variance-skewness framework and compare the efficiency obtained from both of mean-variance model and mean-variance-skewness. The results prove that the efficiency obtained from mean-variance-skewness is approximately or better than evaluating efficiency based on merely mean and variance.

The objective of supplier selection problem is similar to portfolio selection. In portfolio selection, the investors should select portfolios which have optimum return, while in supplier selection problem, buying firm choose supplier which have best performance. Therefore, the concept of mean-variance-skewness could be applied to evaluate supplier's performance before making a choice.



(a) Cost performance which skewed to the right (i.e., positive skew)



(b) On-time delivery performance which skewed to the left (i.e., negative skew)

Figure 2.7 Example of performance skewness

Generally, when selecting supplier, buying firm should select the one which have high expected performance (i.e., mean) and low risk (i.e., variance). But for skewness, it depends on types of performance. For a supplier whose performance has no skewness does not point out that it is good supplier. For instance, and showing in Figure 2.7, if we focus on performance of cost criteria, literally supplier's price could

be fluctuated for a period of time. Assuredly, buyers prefer right-skewed price to either left-skewed or symmetrical price distribution. Similarly but conversely, if we focus on performance of on-time delivery, buyers would be satisfied if supplier can deliver products within shorter period than expectation. In this case, buyers prefer left-skewed performance.

2.5 FMEA Concept

FMEA stands for Failure Mode Effects Analysis. It is first published in 1960 by the US Armed Forces Military Procedures (Dağsuyu, Göçmen, Narlı, & Kokangül, 2016) . It is the approach used for identifying potential failures in the design process of product and process (Almannai, Greenough, & Kay, 2008; L.-H. Chen & Ko, 2009; P.-S. Chen & Wu, 2013; Ekmekçioğlu & Kutlu, 2012) . It is normally used to predict what might go wrong with product or process so it is able to find cause of failure in order to prevent failures to occur and quickly respond to such kind of situation. This tools is widely used in manufacturing. In FMEA, the function or the causes of failure are identified first, then risk priority number (RPN) of each cause is calculated based on three factors as shown in equation below:

$$RPN = S \times O \times D \tag{2.3}$$

Where RPN is risk priority number

S is severity

O is occurrence

D is detectability

All 3 combinations will be rated with number scale from 1 to 10. The meaning of each combination is explained in the following part:

- Severity represents the degree of damage or loss of the worst possible consequence of a failure that could occur. The scale 1 represents low damage or insignificant damage, where 10 represents very high damage or loss could occur.

- Occurrence represents the likelihood of the cause of failure could occur. The scale 1 represents the small chance of cause of failure to occur, in other words, that

cause of failure is not likely to occur. And scale 10 represents the inevitable cause of failure.

- Detectability refers to how well the cause of failure is detected. The scale 1 means the problem is easily to be detected while 10 means the cause of failure is not be able to detect.

After RPN of all cause of problem are calculated, then all causes are ranked based on RPN. Higher RPN denotes greater chance of failure. Therefore, the critical causes can be selected and improved in order to earn higher efficiency.

In supplier selection problem. P.-S. Chen and Wu (2013) did a research which applied FMEA approach to select supplier from risk aspect. In this research after researchers identified set of criteria and important weight by using AHP technique, then the modified failure mode effects analysis (MFMEA) was conducted. The potential failure mode of each criteria were identified. After that, the level of each combination in FMEA were determined but the researchers used only 4 scale ratings rather than ordinary scale from 1 to 10. For example, scales of severity of cost criteria and quality criteria are shown below:

- 1-Remote — Cost: supplier offers cheap price; Quality: suppliers offers few defects
- 2: Low — Cost: supplier offers middle price; Quality: suppliers offers some defects
- 3: Moderate — Cost: supplier offers high price; Quality: suppliers offers many defects
- 4: High — Cost: supplier offers expensive price; Quality: supplier offers abundant defects

Then, the RPN was calculated. Then the result of RPN and important weight of each sub-criterion are multiplied together in order to calculate total weight RPN. The steps of MFMEA method is shown in Figure 2.8.

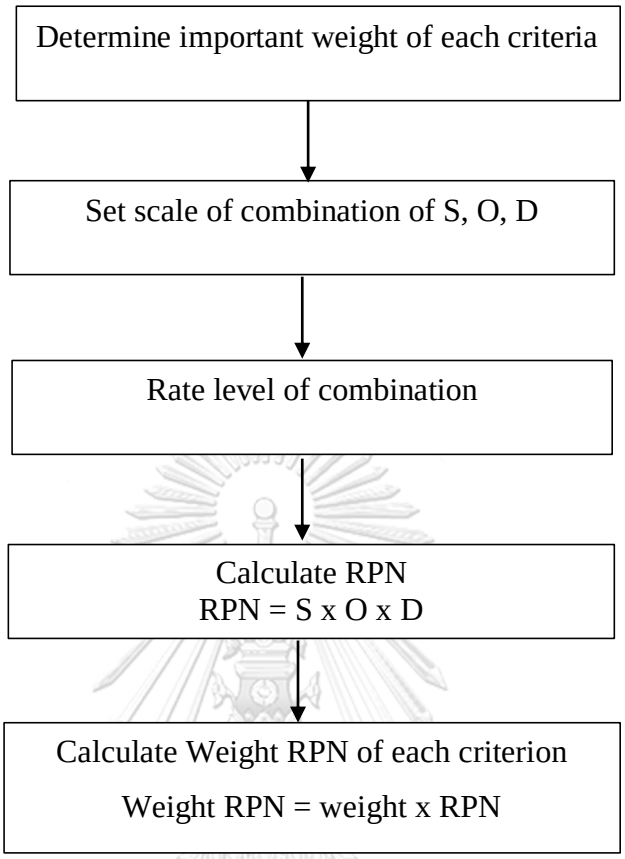


Figure 2.8 *Steps of MFMEA method for supplier selection*

Table 2.9 presents the example of calculating weight RPN in order to select the best supplier. Assuming that there are 2 main criteria (A-B) with totally 5 sub-criteria (A1-B3). After obtaining important weight from AHP approach, then S, O and D of each sub-criteria are evaluated in order to calculate RPN of each sub-criterion. As seen in Table 2.9, the total weight RPN of this supplier is 5.25. By this same steps, the total weight RPN of other potential suppliers could be calculated.

Table 2.9 *Calculating weight RPN using MFMEA approach*

Supplier A							
Main criteria	Sub-criteria	Weight	Risk assessment			RPN	Weight RPN
			S	O	D		
A	A1	0.1	1	1	1	1	0.1
	A2	0.2	2	2	1	4	0.8
B	B1	0.15	2	1	1	2	0.3
	B2	0.3	3	2	1	6	1.8
	B3	0.25	1	3	3	9	2.25
						Total	5.25

Supplier A							
Main criteria	Sub-criteria	Weight	Risk assessment			RPN	Weight RPN
			S	O	D		
A	A1	0.1	2	2	1	4	0.4
	A2	0.2	1	2	3	6	1.2
B	B1	0.15	2	2	1	4	0.6
	B2	0.3	3	3	1	9	2.7
	B3	0.25	2	4	2	16	4
						Total	8.9

Supplier with lower weight RPN means suppliers with less risk to purchase from. From Table 2.9, there are 2 potential suppliers, A and B. To compare between these 2 suppliers, buyer should select supplier A as its total weight RPN is less than B which means purchasing from supplier A has lowest risk than supplier B. Therefore, by using MFMEA to select supplier, buyer will be able to select the most proper supplier who has lowest potential failure.

Applying FMEA concepts to supplier selection is the selection to avoid possibility to be failure of supplier. In other words to avoid suppliers who perform worse than expected. If the measurement of potential failures can be applied on supplier

selection problem, measurement of possibility to be success should be able to apply on supplier selection.

2.6 Research Gap

From literature review, some research gaps are found as described in following section:

1. Even though evaluation method based on mean-variance-skewness (M-V-S) has been using in portfolio selection problem, but in logistics research, no one ever applied this concept on supplier selection problem.

2. There is a small number of research exploring the importance and the effect of skewness. And none of research including skewness effect on supplier selection field is existed.

Therefore, this research aims to study the importance of skewnss in supplier performance and develop decision matrix to valuate supplier performance by measuring the possibility to be success which comprises of 3 combinations, which are, mean, standard deviation, and skewness.

CHAPTER 3
METHODOLOGY

This chapter first explains about the methodology. Then, the initial set of criteria is shown along with ANP model. Questionnaire design are proposed. The data collecting and target group are discussed.

3.1 Research Framework and Research Methodology

To response to research questions and objectives, this research can separated into two parts as shown in Figure 3.1. First part is to identify critical criteria as well as its important weight of buyer's decision. Since supplier selection criteria have effect on each other (Eshtehardian et al., 2013). In other words, the criteria are interrelated. Therefore, in this part, the preference of criteria is compared and analyze by using ANP technique. The second part is evaluating performance of potential suppliers by evaluating mean, variance and skewness of performance. Then combine the results from both parts to make a final decision who is the best supplier among those potential suppliers.

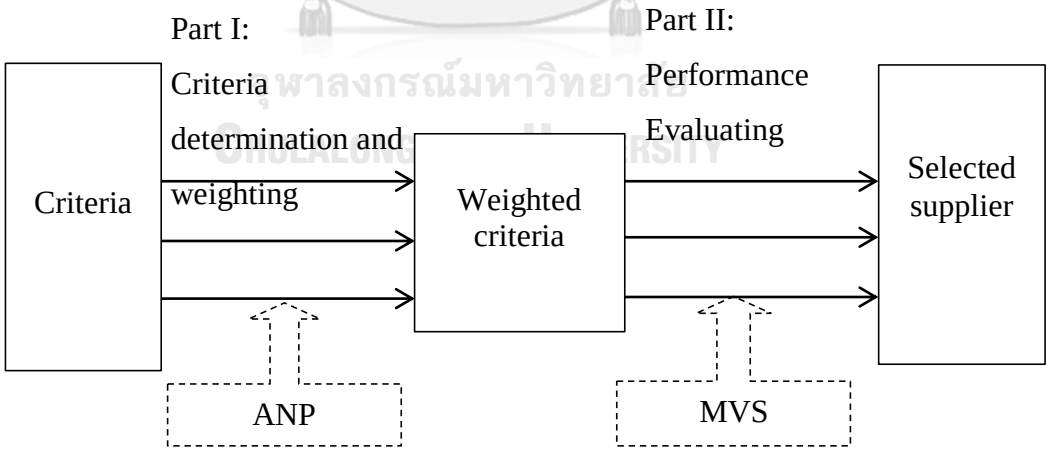


Figure 3.1 Research framework

According to achieve the objectives of this research, there are several steps as shown in Figure 3.2.

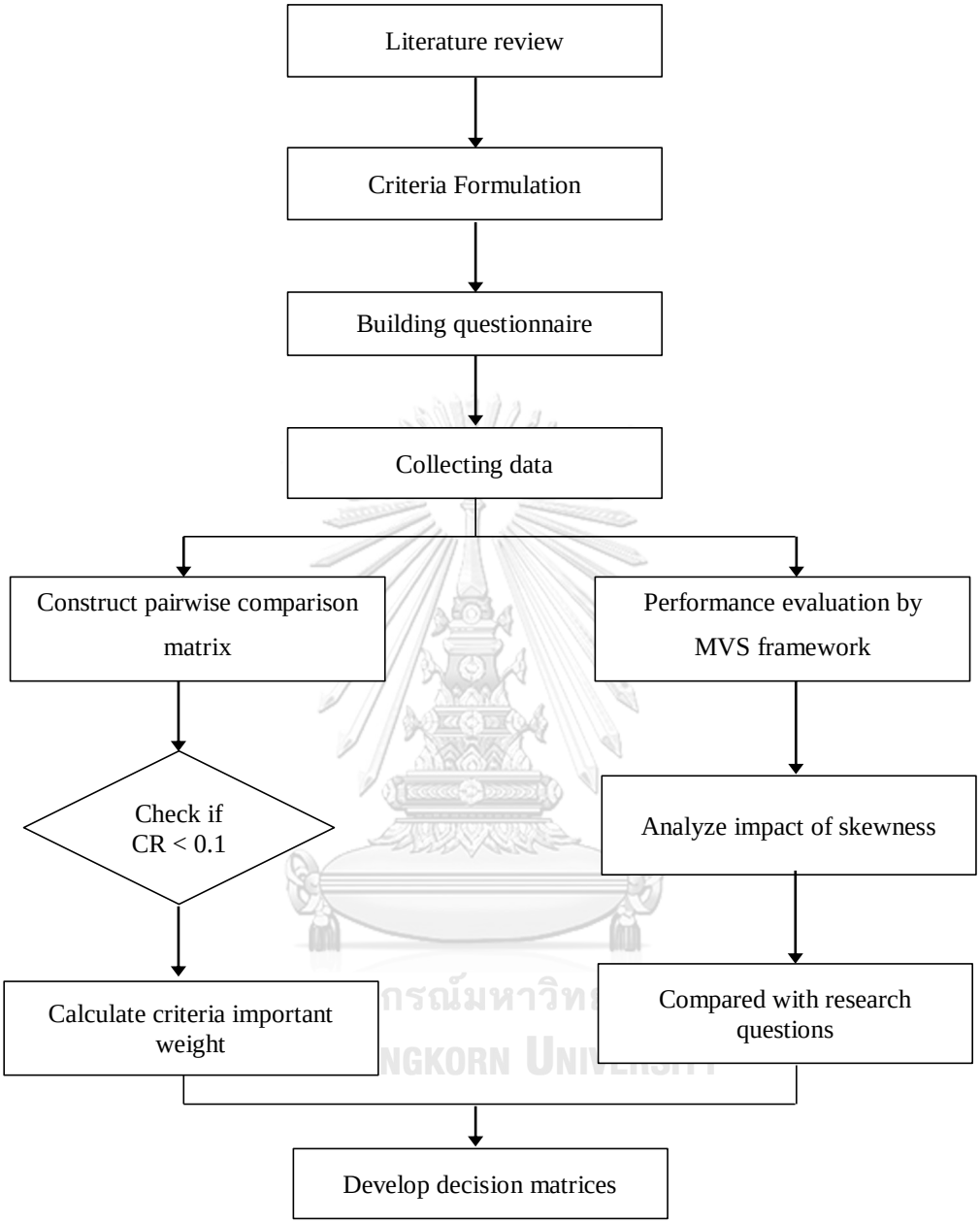


Figure 3.2 Research methodology

3.2 Criteria Formulation

Obviously, supplier selection problem is multi criteria decision problem which consists of quantitative and qualitative criteria (Cengiz, Aytekin, Ozdemir, Kusan, & Cabuk, 2017). Therefore, one of research questions is, for Thailand industry, what are

the criteria of supplier selection that buying firms concern. At first, critical criteria are gathered from literature review of previous studies based on Dickson's criteria in 1966. Then 25 literatures are studied in order to extract influential criteria and shown in Table 2.2 in chapter 2. Totally, it has 27 criteria including Dickson's criteria and additional criteria from previous studies. From summary of frequency used of criteria, most widely used criteria are selected. Cutoff point between possibly impossibly influential criteria in this research is 12% of used. From Table 2.2 in chapter 2, there are 16 criteria which have at least 12% of used as shown in Table 3.1.

Table 3.1 Criteria with % of used greater than 12%

Criteria type	Criteria	% of used
Dynamic	Quality	96
	Delivery	92
	Cost	84
	Production facilities and capacity	44
	Technical capability	44
	Service ability	24
	Flexibility	20
	Green supplier	20
	Procedural compliance	12
	Relationship	12
Static	Financial position	28
	Geographical location	28
	Management and organization	24
	Communication system	16
	Warranties and claim policies	12
	Reputation and position in industry	12

To retrieve the final set of criteria, first, criteria are classified into 2 types. First is dynamic criteria which means criteria that it performance changes all the time. Another type is static criteria which means criteria with constant performance or criteria which hardly fluctuated all the time, for example, geographical location. Location problem is the decision in strategic level. Once the location is selected and facility is established, it will be used for a long period. Performance of this criteria cannot change easily, therefore, it is classified as static criteria. This research intends to study uncertainty in supplier selection, therefore, only dynamic criteria are considered.

Also criteria which have similar characteristics are combined together. The first pair is production facilities and capacity, and flexibility. Based on their definition, production facilities and capacity refers to being responsive in terms of order quantity changing from customer, while flexibility refers to being responsive, not only for order quantity changing but also changing of design, process or product specification. Both of them have similarity in characteristics of being responsive. Therefore these 2 criteria are combined together and renamed as capacity and flexibility in order to reduce the number of criteria. Another pair is combining between service ability and relationship. Both of them have similarity of well collaboration from suppliers. Therefore, these 2 criteria are combined together and renamed as collaborative development.

From all of dynamic criteria, they are classified into 5 groups, which are, cost, delivery, quality, green supplier, and others which comprises of the left criteria as shown in Figure 3.3.

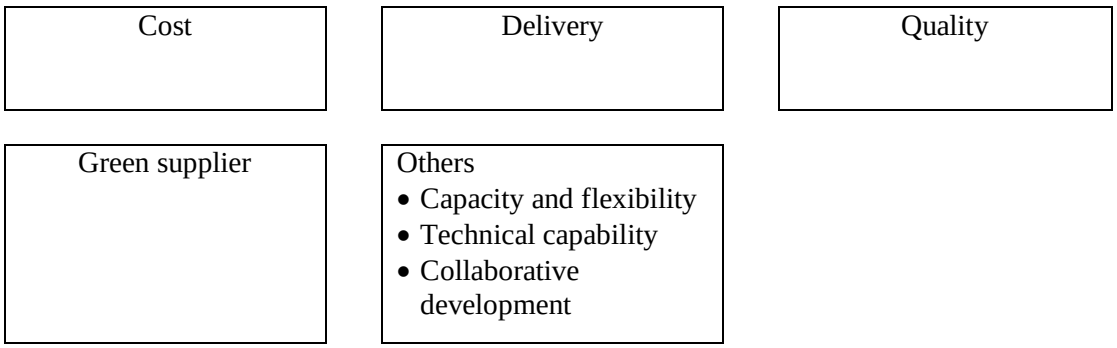


Figure 3.3 Main criteria

After main criteria are set, each main criteria are divided into sub-criteria in order to evaluate supplier performance in deeper details. Figure 3.4 illustrates all main criteria as well as sub criteria in each main group.

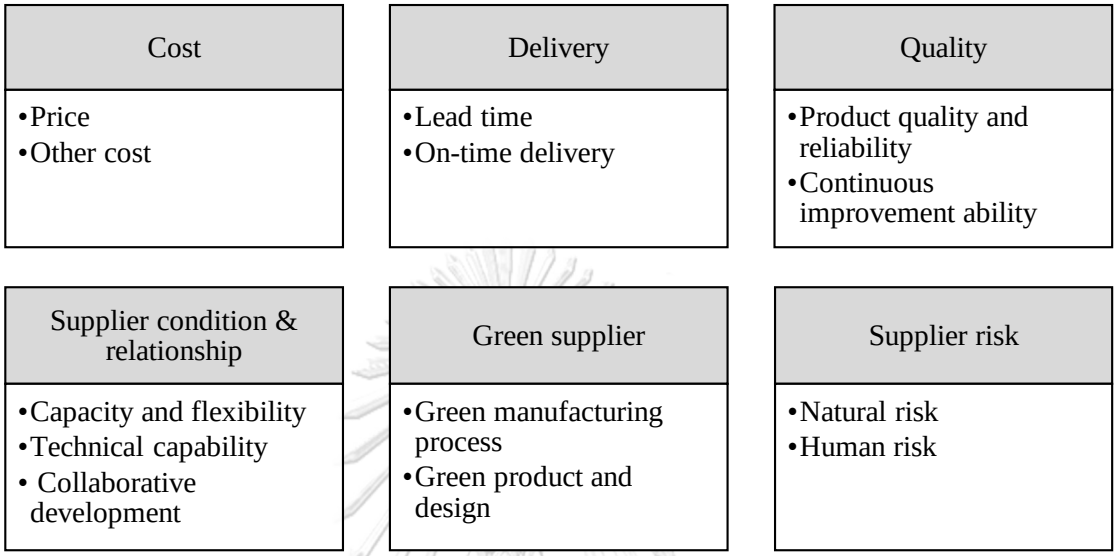


Figure 3.4 Criteria grouping

Totally there are 6 main criteria with 13 sub-criteria in this research. The following parts explain each critical criterion and its definition.

1) Cost: One of the most important criteria for supplier selection is cost which means the overall expense spending to receive product from supplier. It has 2 sub-criteria:

- Price which means the total price offered from supplier.
- Other cost which means the additional cost other than product price, such as transportation cost, operating cost.

2) Delivery: This criterion means ability of supplier to provide product to buyer or manufacturer. In nowadays business environment which tends to compete with rivals by improving ability to be able to meet customer demands in shorter time, especially in electronics industry, supplier delivery performance has much effect to manufacturer's performance. It has 2 sub-criteria:

- Lead time which means the time period used between when placing order to supplier until receiving.
- On-time delivery means the delivery performance of supplier to fulfill ordered quantity to manufacturer in the expected time by customer.

3) Quality: Together with cost and delivery, one of the basic supplier's requirements is quality of product as well as reliability. This main criterion has 2 sub-criteria:

- Product quality and reliability means the quality of product which meets buying firm's specification and supplier reliability and consistency of product quality. The performance of this criterion can be measured by return rate.
- Continuous improvement ability, this sub-criterion is about effort and ability of supplier to increase performance for the future.

4) Supplier condition and relationship: This is a criterion related to supplier's current condition affecting to buyer or manufacturer and relationship between buying firm and supplier which included 4 sub-criteria:

- Capacity and flexibility means ability to produce order from buyer with big quantity and responsiveness to changing or additional requirement from buyer, such as product specification, quantity and procedure.
- Technical capability is the technological proficiency of supplier, not only the current one but also the potential of future technological research and development (R&D) both of product design and production process.
- Collaborative development is the cooperation from supplier and buying firm to improve their capability and efficiency in terms of product development and process development.

5) Green supplier: Nowadays environmental awareness has been growing. Therefore, one of the main criteria to select supplier is green supplier which is the consideration of supplier on environment. It is comprises of 2 sub-criteria:

- Green manufacturing process is the awareness and ability of supplier to lower consumption of resource and reduce impact on environment in production process.

- Green product and design is the ability of supplier to design and develop environmentally-friendly product. For example, use less hazardous material or recyclable material.

6) Supplier risk: Once a buying firm already makes a decision, there is a possibility that supplier performance would not be as expected. Thus this research adds supplier risk to be one of the main criteria which divided into 2 sub-criteria:

- Natural risk is related to possibility of lower expected performance caused from natural events.
- Human risk is related to possibility of lower expected performance caused from human.

After initial set of criteria has been formulated, the next step is confirming the propriety of criteria. Surveying questionnaire asking to confirm and judge the suitability of each criterion is constructed and distributed to companies in Thai electronics industry to confirm appropriateness of the set of initial criteria (see Appendix A). The respondents are purchasing and procurement manager with at least 15 years of experience. Questionnaire were sent to 20 respondents and 13 questionnaires were received with 65% response rate. The result of pre-screening set of criteria is shown in Table 3.2. Number 1 represents agreement of respondent on suitability of criterion while number 0 represents vice versa that criterion does not affect to supplier selection. Each criterion will be remained as final set of criteria if more than half of respondents are agreed with that criteria.

The result in Table 3.2 shows that 7 from 13 respondents or 53.85% are completely agreed with initial set of criteria. Eight sub-criteria has 100% of agreement which means these criteria are agreed by all respondents. Some sub-criteria has low percent of agreement compared with criteria with 100% of agreement, for example, natural risk within main criteria of supplier risk, has 69.23% of agreement. But it is in the range of acceptable (9 from 13 respondents are agreed with this criteria). Hence, all set of criteria are still remained.

Table 3.2 Result of pre-screening set of criteria

Main Criteria	Sub-criteria	Respondent													% agree-ment
		1	2	3	4	5	6	7	8	9	10	11	12	13	
Cost	Price	1	1	1	1	1	1	1	1	1	1	1	1	1	100
	Other cost	1	1	1	1	1	1	1	1	1	1	1	1	1	100
Delivery	Lead time	1	1	1	1	1	1	1	1	1	1	1	1	1	100
	On-time delivery	1	1	1	1	1	1	1	1	1	1	1	1	1	100
Quality	Product quality and reliability	1	1	1	1	1	1	1	1	1	1	1	1	1	100
	Continuous improvement ability	1	1	1	1	1	1	1	1	1	1	1	1	1	100
Supplier condition and relationship	Capacity and flexibility	1	1	1	1	1	1	1	1	1	1	1	1	1	100
	Technical capability	1	1	1	1	1	1	1	1	1	1	1	1	1	100
	Collaborative development	1	1	1	1	1	1	1	1	0	1	1	1	1	92.31
Green supplier	Green manufacturing	0	1	1	1	1	1	0	1	0	1	1	1	1	76.92
	Green product and design	1	1	1	1	1	1	0	1	0	1	1	1	1	84.62
Supplier risk	Natural risk	0	1	0	0	1	1	1	1	1	0	1	1	1	69.23
	Human risk	0	1	0	0	1	1	1	1	1	1	1	1	1	76.92

3.3 ANP Model

Because of the existence of relationships among criteria, therefore the structure of criteria is constructed based on ANP approach as shown in Figure 3.5. All main criteria has effect to buyer's judgment when selecting supplier and also the relationship among main criteria exists. The arcs in the picture represents the relationship among criteria. For example, criteria of cost, not only sub-criteria, price and other cost have influence on this main criteria but also other main criteria. Hence, there are links between cost and other main criteria. This implies that one main criteria might have effect on other criteria. For example, high quality products tend to consume higher cost

which means there is relationship between the criteria of cost and quality. Moreover, not only relationship between sub-criteria within the same main criteria existed but also the outer criterion dependency relationship among main criteria. This leads to more than 800 pairs to compare, therefore, some links which the author decided that no relationship existed have been removed.

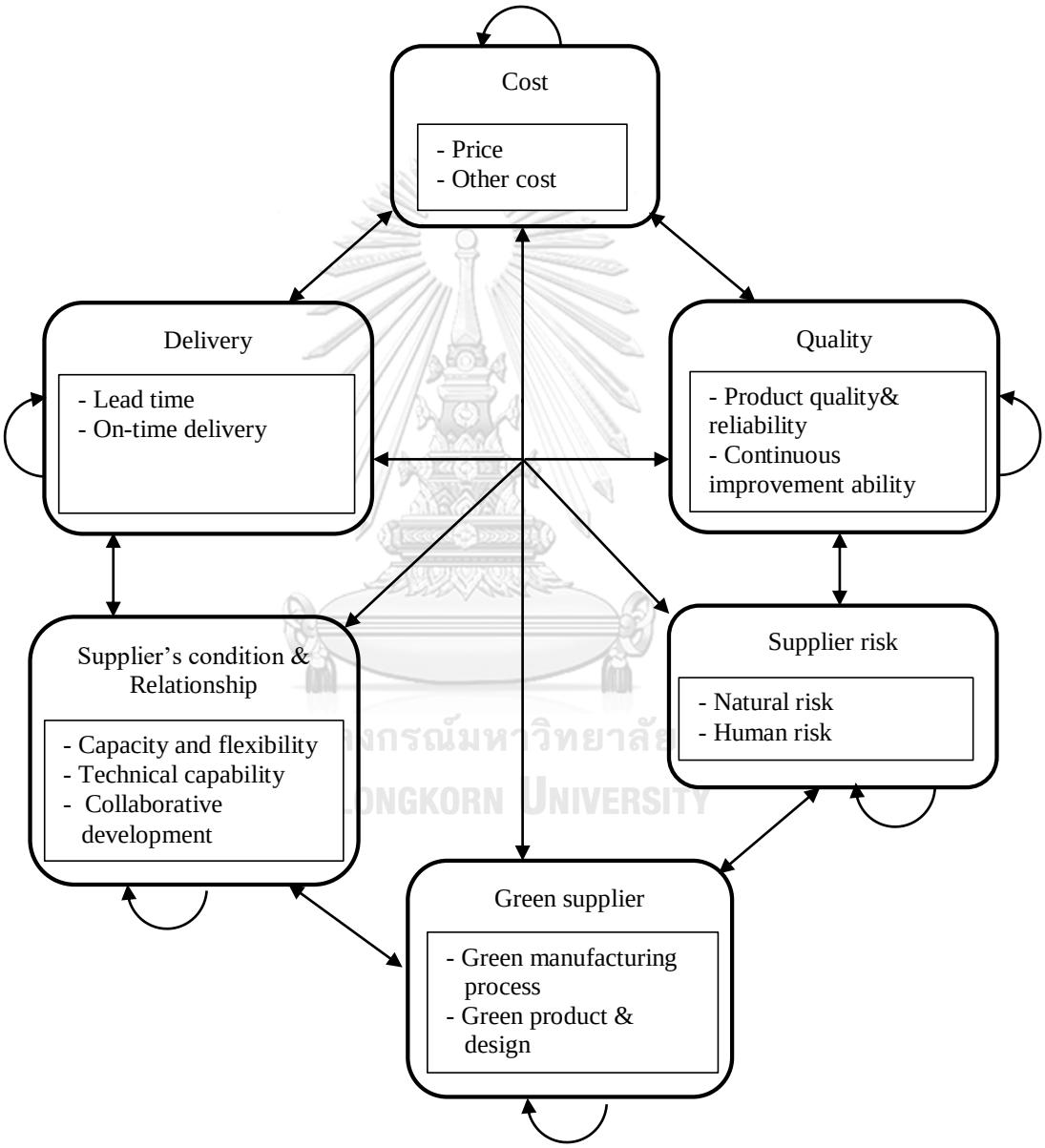


Figure 3.5 The structure of criteria in ANP for supplier selection

3.4 Building Questionnaire

After the set of criteria is confirmed by experts, the questionnaire is asking about criteria weight and performance evaluation is constructed (see appendix B). Questionnaire is separated into 2 main sections. First section is used for criteria weighting, another section is used for performance evaluating.

3.4.1 Design of Questionnaire: Section 1

For the first section, questionnaire is designed to ask the respondents to compare a given pair of criteria followed Saaty's rating scale (1-9) as follows:

- 1-Equal importance — One criteria will influence 1 times more on a given element than the other does.
- 2: Equal to moderate importance — One criteria will influence 2 times more on a given element than the other does.
- 3: Moderate importance — One criteria will influence 3 times more on a given element than the other does.
- 4: Moderate to strong importance — One criteria will influence 4 times more on a given element than the other does.
- 5: Strong importance — One criteria will influence 5 times more on a given element than the other does.
- 6: Strong to very strong importance — One criteria will influence 6 times more on a given element than the other does.
- 7: Very strong importance — One criteria will influence 7 times more on a given element than the other does.
- 8: Very strong to extreme importance — One criteria will influence 8 times more on a given element than the other does.
- 9: Extreme importance — One criteria will influence 9 times more on a given element than the other does.

In this section, questions are divided into 5 parts based on the level of preference structure, such as, level of relative importance among all main criteria by assuming

criteria are independent, level relative importance among main criteria by assuming interrelation among criteria, etc. The structure of questionnaire can be explained as follows:

Let C1: cost criteria

C_2: delivery criteria

C_3: quality criteria

C_4: supplier's condition and relationship criteria

C_5: green supplier criteria

C_6: supplier risk criteria

- Part 1: This part is to measure the relative importance among all main criteria on supplier selection by assuming existence of dependency relationship as illustrated in Figure 3.6.

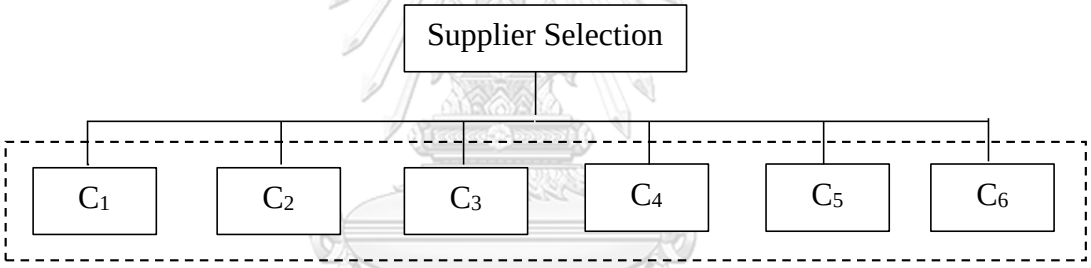


Figure 3. 6 The comparison of relative importance among all main criteria on supplier selection

- Part 2: This part is to measure the relative importance among main criteria by assuming interrelation among main criteria. To collect the data for this part, respondent will be asked to judge the relative influence between each pair of main criteria on the specific main criteria as shown in Figure 3.7.

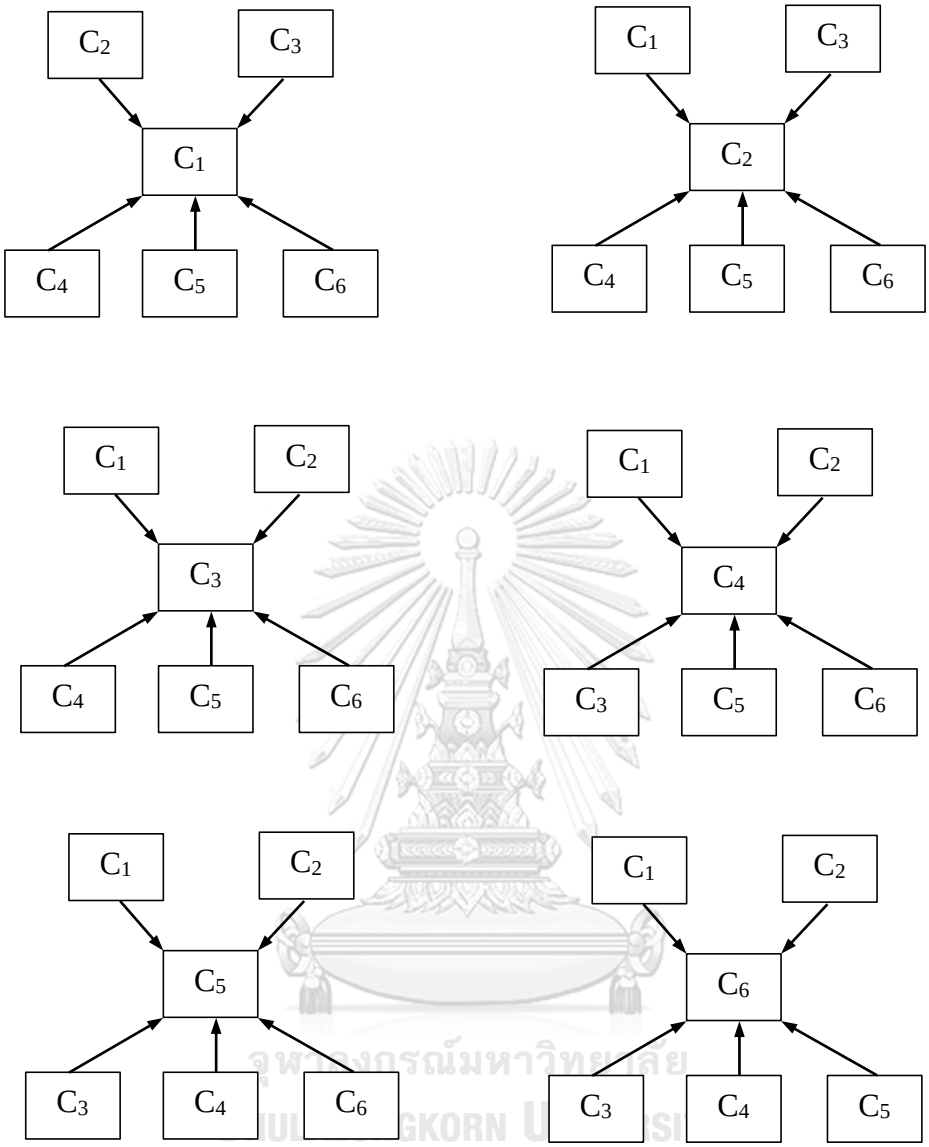


Figure 3. 7 The comparison of relative importance among main criteria by assuming interrelation among main criteria

- Part 3: This part is to measure the relative importance among sub-criteria with respect to their main criteria.

Let e_{ij}: sub-criteria j of main criteria i

e_{11}: price

e_{12}: other cost

e_{21}: lead time

e_{22}: on-time delivery

e_{31}: product quality and reliability

e_{32}: continuous improvement ability

e_{41}: capacity and flexibility

e_{42}: technical capability

e_{43}: collaborative development

e_{51}: natural risk

e_{52}: human risk

e_{61}: green manufacturing process

e_{62}: green product and design

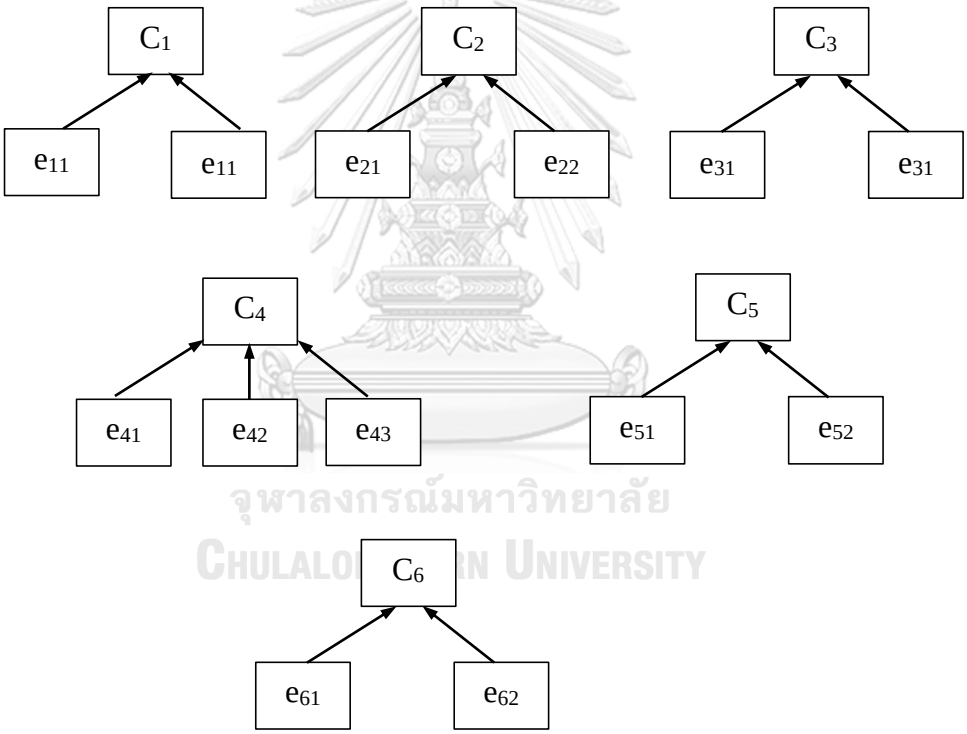


Figure 3. 8 The comparison of relative importance among sub-criteria with respect to their main criteria

- Part 4: This part is to measure the relative importance among sub-criteria by assuming existence of criterion dependency relationship under their main criteria.

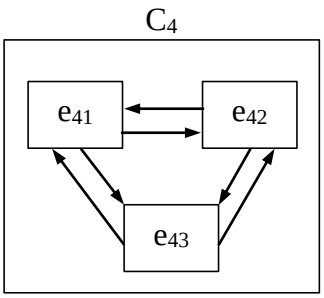


Figure 3.9 The comparison of relative importance among sub-criteria by assuming existence of criterion dependency relationship under their main criteria

- Part 5: This part is to measure the relative importance among all criteria by assuming existence of outer criterion dependency relationship among main criteria. For example, Figure 3.10 illustrates influence among all sub-criteria on sub-criteria of price (e_{11}). It shows that not only relationship within main criteria of cost exists but also outer criteria are included.

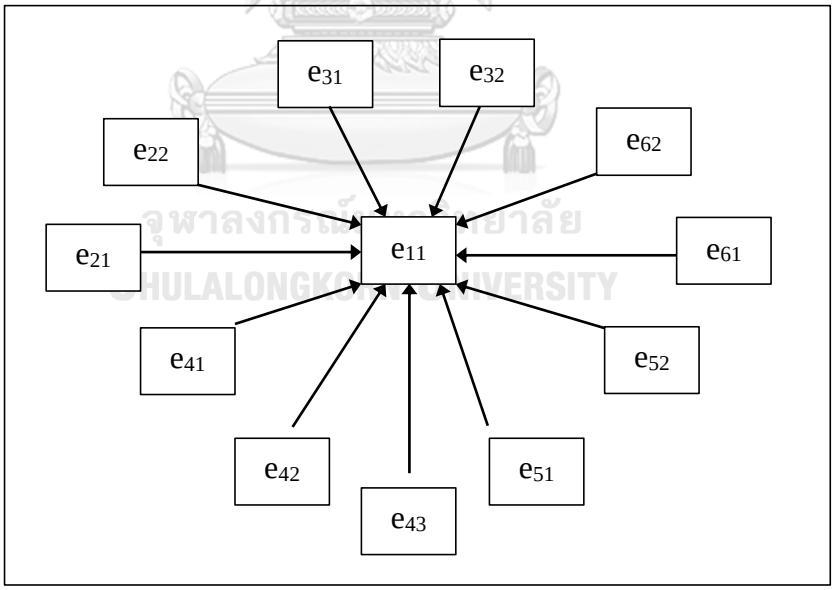


Figure 3.10 The comparison of relative importance among all criteria by assuming existence of outer criterion dependency relationship among main criteria

3.4.2 Design of Questionnaire: Section 2

The second section of questionnaire is designed to ask the respondents (i.e. purchasing manager) to evaluate historical performance of potential suppliers for each criteria. In questionnaire, respondent will be asked to evaluate between two current suppliers, namely supplier A and supplier B. The questions in this section is separated into two parts. In part 1, the respondent will be asked to select current two suppliers who can provide same material or part. One is supplier who has first priority to be selected, in other words, this represents good supplier. Another one is supplier who would be the last choice to be selected or bad suppliers which express bad supplier. In part 2, the respondent will be asked to rate performance of each supplier based on each criteria. Performance will be measured in three characteristics:

1. Performance Efficiency refers to the expected of efficiency of supplier measured by mean.

2. Performance Stability refers to standard deviation. Because good supplier should provide constant performance or standard deviation of supplier's performance should be low.

3. Performance Tendency refers to skewness. As mentioned earlier, it does not mean that supplier with no tendency to differ from average efficiency or not fluctuate is good. Hence, this performance reflect the asymmetrical direction of efficiency which measured by skewness.

Asking respondent to evaluate suppliers' standard deviation and skewness is not easy. In order to obtain these two characteristics, the respondent will be asked to evaluate lower and upper bound of performance, i.e. minimum and maximum level of criterion performance and most often occurred performance, i.e. mode which provided by each supplier. The standard deviation will be calculated using the estimation of range, i.e. the difference between maximum and minimum level of performance obtained from questionnaire. This estimation is proved and proposed by Hozo, Djulbegovic, and Hozo (2005) and it is showed in equation 3.1. The skewness will be calculated using pearson's coefficient of skewness which is estimating skewness by mean and mode obtained from questionnaire as shown in equation 3.2.

$$SD = \frac{Range}{6} \quad (3.1)$$

$$Sk = \frac{\overline{X} - mode}{SD} \quad (3.2)$$

Where SD is standard deviation

$Range$ is difference between lowest and highest of the range

Sk is skewness

$Mode$ is most often occurred performance

3.5 Determining Target Group and Data Collecting

Although this research has set manufacturers in electronics industry as target group. But there is a large number of manufacturers in this industry. Also, characteristics of manufacturers in this industry are very heterogeneous due to many types of products and manufacturers. A method that could be used to classified manufacturing types is using TSIC. TSIC is a 5-digit-code generated by Department of Industrial Works, Ministry of Industry. Based on TSIC, manufacturing companies in electronics industry can be grouped into 7 types which are;

1. Electronic devices, part and coil
2. Computer storage equipment
3. Lighting equipment
4. Transformer, uninterrupted power supply, battery, electric wire
5. Computer part, Print circuit board, electronic mainboard
6. Home Electrical machine
7. VDO recorder, camera, lens

After classifying all manufacturers in electronics industry based on TSIC code, each type still has large number of manufacturer. Then manufacturers in each type are classified based on size of company using Small and Medium Enterprises Promotion Act, B.E. 2543. Based on the rule of this promotion act, size of manufacturers can be classified into 3 categories, small, medium and large enterprise by these following rules;

- Small-size-manufacture (S): number of employees is not greater than 50 employees or asset value is not greater than 50 million baht.
- Medium-size-manufacturer (M): number of employees is between 51-200 employees or asset value between 50-200 million baht.
- Large-size-manufacturer (L): number of employees is greater than 200 employees or asset value is greater than 200 million baht.

Finally, manufacturers in electronics industry can be re-group based on its character and product type (manufacturer type based on TSIC) as well as size of company (based on Promotion Act) as shown in Table 3.3.

Table 3. 3 Clustering of Thailand's electronics industry

Types of manufacturer	Size of company		
	S	M	L
Electronic devices, part and coil	152	28	7
Computer storage equipment	25	4	2
Lighting equipment	50	24	9
Transformer, uninterrupted power supply, battery, electric wire	270	138	48
Computer part, Print circuit board, electronic mainboard	22	16	34
Home Electrical machine			
- Stereo, Television	502	177	162
- Refrigerator, Fan, washing machine, air-conditioner	493	173	78
- Other home electrical machines	23	1	1
VDO recorder, camera, lens	11	12	12
Total	1548	573	353

Source: Department of Industrial Works, Ministry of Industry (31 Jan 2016)

In this research, home electrical machine which is the nearest tier to end customer has been selected as target group. Because suppliers of this manufacturing type are companies who produce, for example, electronics device, motor, coil, electric wire, which are still in electronics industry. But if electronics devices are selected as target group, suppliers of this manufacturing type fall on other industry, such as, plastic industry, steel industry, rubber industry. Home electrical machine is selected in order to avoid such circumstance. Also only M and L-size-manufacture are selected as target group. Because of small manufacturers are possibly to have no standard and no system, the result may has much variance if small-sized manufacturers are including. Hence, total population size is 592 companies.

CHAPTER 4
RESULT ANALYSIS

This chapter presents result of data analysis obtained from the survey. First, summary of respondents are presented, follows by criteria important weight and result of performance evaluating. Then the skewness effect is analyzed. Finally, decision matrix of supplier selection is proposed.

4.1 Summary of Respondents

After set of criteria were formulated and questionnaire was constructed, then the data survey was begin as mention in precious chapter. To determine sample size, this research refers to sample size from previous researches which applied similar method, i.e. MCDM techniques. Table 4.1 presents number of sample size from previous researches.

Table 4. 1 Number of sample size from previous researches

No.	Year	Authors	Sample size
1	1998	Verma & Pullman	58
2	1999	Yahha & Kingsman	16
3	2005	Lie & Hai	60
4	2007	Gurpina	16
5	2012	Bruno et al.	20
6	2014	Dargi et al.	4
7	2014	Lima et al.	3

From Table 4.1, the maximum sample size from previous studies are 60. Therefore, this research set minimum sample size required equals to 60 sample sizes. After the sample size is determined, then the survey is conducted by two ways. One is face-to-face interview, another one is questionnaire distribution.

- Questionnaire: For questionnaire, totally 30 questionnaires were distributed to medium and large size manufacturers and 24 questionnaires were received, with 80% response rate.

- Face-to-face interview, 53 companies were interviewed.

Figure 4.1 shows the ratio of face-to-face interview to questionnaire samples. Totally, the sample sized in this research is 77 companies. The ratio of face-to-face interview to questionnaire is about 69% to 31%. The data obtained from interview is more precise and correct as it is two-way communication. Respondents are allowed to ask immediately if there is any question or confusion. Also, collecting data by distributing questionnaire is likely to have more mistake, especially in questionnaire section 1. For interviewing, the inconsistency ratio can be calculated along with interviewing. So if there is any inconsistency, respondent will be asked to re-judgment the comparison instantly. But using questionnaire, after receiving questionnaire from respondent and it is found inconsistency in the comparison, questionnaire will be sent back to respondent. Then after receiving questionnaire, the result will be analyzed again. If there is still inconsistency, then the questionnaire will be sent back to respondent again. Therefore, if the case company is located in Bangkok and nearby province, the interview is first priority. But if the case company is located in other region, questionnaire is used instead of interviewing due to limitation of time and traveling cost.

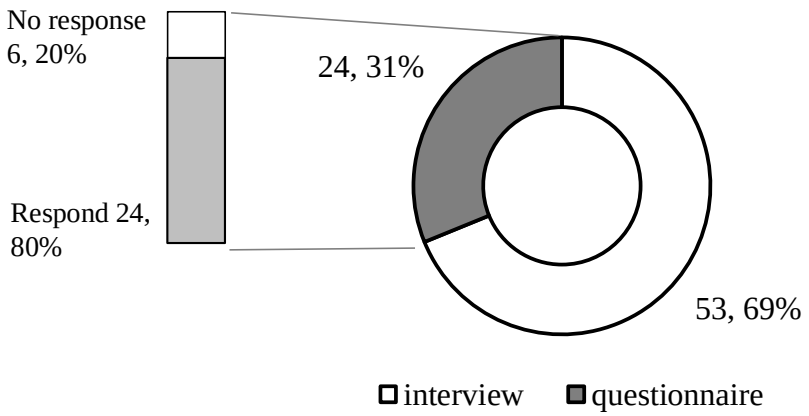


Figure 4.1 Sample size classified by surveying method

As we requested deep information and also the respondents in this research is purchasing manager and procurement manager which required at least 10 year of experience. Therefore, small sample sized is acceptable as the comparison sample size between previous studies shown in Table 4.2. The average year of experience of respondents are 15.87 years. Table 4.1 presents the data of sample size in this research classified by type and size of manufacturers. From total sample size of 77 companies, 42 of them or 55% are medium-sized companies and 35 of them or 45% are large-sized companies as illustrated in Figure 4.2.

Table 4.2 The characteristics of sample size

Type of manufacturers	Sample size	
	M	L
Stereo, Television	16	17
Refrigerator, Fan, washing machine, air-conditioner	25	18
Other home electrical machines	1	0
Total	42	35

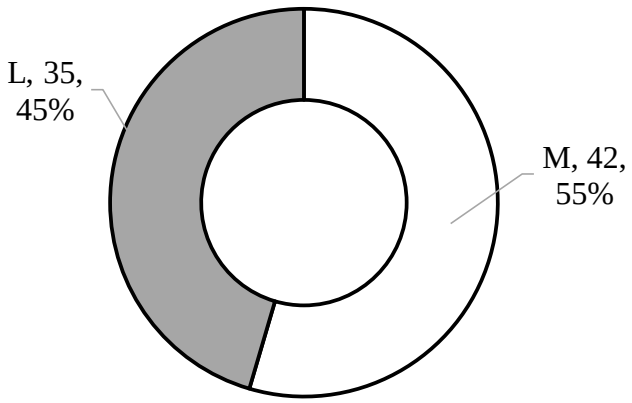


Figure 4.2 Sample size classified by size of company

As presented in Figure 4.3, respondents consists of three types of companies: Thai company, joint company between Thai and foreign company and foreign company.

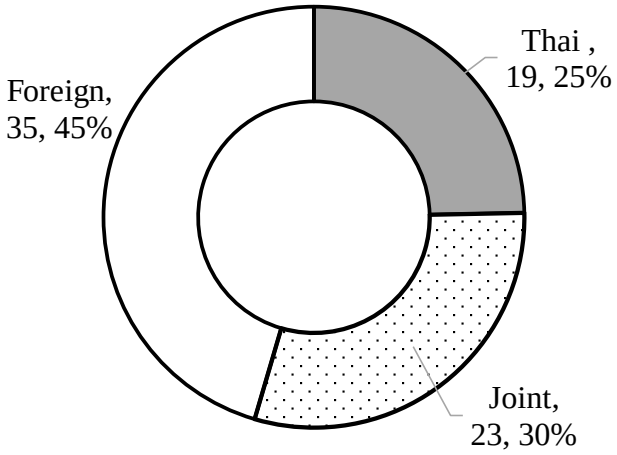


Figure 4.3 Sample size classified by types of company

Purchasing and procurement experts from each company was interviewed or requested to fill out the questionnaire asking to evaluate and compare performance between key supplier which is recognized as supplier with good performance and unfavorable supplier which is recognized as bad supplier who would be the first and the last choice to be considered when buying, respectively, in order to analyze whether it has different performance perspective between these two suppliers, especially skewness.

4.2 Importance of Criteria

4.2.1 Overall Criteria Importance

In this research, ANP approach is used to analyze important weight of criteria. Compare among main six criteria or dimension, supplier condition and relationship is the most important criteria, follows by delivery, cost, quality, supplier risk, and green supplier respectively. It is surprisingly that CQD (Cost; Quality; Delivery) are not the top-3 criteria as people always thought. But manufacturers in Thai electronics industry concern most about supplier condition and relationship which mostly rely on the flexibility and technical capability. Because of competitive environment tends to become more severe, more customization and more rapid, competition becomes more intense. Then supplier must be able to meet customers' need rapidly.

In sub-criteria level, the overall results show that among all sub-criteria, Lead time is the most important criteria, follows by Price, Continuous improvement ability, Capacity and flexibility, Product quality and reliability. The least important criteria is Collaborative development. The overall rank as well as each criterion weight is presented in Table 4.3.

The overall results reflect well on the behavior of customer in electronics industry. With technology changes so fast and intense competition, lead time is the most concerning criterion in buyers' view with 0.0910 weight score. The second criterion is price with 0.0869 weight score. The third rank is continuous improvement ability with 0.0806 weight score. It is surprisingly that buyers concern more on the effort and ability of supplier to increase performance for the future rather than current quality of product to meet firm's specification, i.e. product quality and reliability, which is in the fifth rank. The forth rank is capacity and flexibility which means the ability to produce order from buyer with responsiveness to changing or additional requirement from buyer. Due to customers' needs of responsive, this is not peculiarly result.

Table 4.3 Relative importance of criteria by ANP analysis

Main criteria	Sub-criteria	Overall Weight	Overall Rank	Dimension Rank
Cost	Price	0.0869	2	3
	Other cost	0.0751	8	
Delivery	Lead time	0.0910	1	2
	On-time delivery	0.0750	9	
Quality	Product quality and reliability	0.0786	5	4
	Continuous improvement ability	0.0806	3	
Supplier condition and relationship	Capacity and flexibility	0.0791	4	1
	Technical capability	0.0766	6	
	Collaborative development	0.0678	13	
Green supplier	Green manufacturing	0.0711	11	6
	Green product and design	0.0690	12	
Supplier risk	Natural risk	0.0755	7	5
	Human risk	0.0736	10	

An issue should not overlook is, even though people always talk about being environmental friendly, and raise awareness of green issue, in fact buyers seem not to care for this criteria as green supplier is the least important main criteria. Also, both of sub-criteria of green supplier are ranked in eleventh and twelfth place.

4.2.2 Criteria Importance Classified by Size of Company

Classified by size of company, important weight of each criterion between medium and large size company are not much different as shown in Figure 4.4. However, their criteria rank are slightly different due to their characteristics. For medium-sized manufacturers, the most affecting criteria on buyers' decision is price, follows by lead time, product quality and reliability, continuous improvement ability, and capacity and flexibility. While the most concerning factor for large-sized manufacturers is lead time, follows by price, technical capability, continuous improvement ability, and other cost. The reasons of this difference is, medium-sized manufacturers have more limited resource than large manufacturers, especially financial resource. Therefore, price criteria is the most important thing that medium-sized manufacturers concern while L-sized manufacturers seek for rapid suppliers who provided short lead time.

Table 4.4 compares rank of criteria importance among medium-sized manufacturers, large-sized manufacturers, and overall result. From this table, although important weights of the same criteria are not much different but rankings are slightly different. The first top-2 important criteria of both sizes are price and lead time, same as overall rank but different place. While L-sized manufactures concerned much about technical capability as this sub-criteria is ranked in third place, M-sized manufacturers concerned about product quality and reliability. This is because L-sized manufacturers have sufficient resource and power over other manufacturers, so they would want to be leaders in the industry. To become trendsetters, they need high technical supporting in terms of designing new product and developing new technology.

About criteria with lowest important weight, bottom-3 criteria which have lowest important weight of L-sized manufacturers are collaborative development, green

manufacturing, green product and design, same as overall ranking. But for M-sized manufacturers, bottom-3 ranked criteria are collaborative development, green product and design, and technical capability, which is the remarkable result. While technical capability is the third ranked criteria that large-sized manufacturers concern but it seems to have less important to medium-sized manufacturers. This is because the opposite reason with L-sized manufacturers'. Medium sized manufacturers have less resource than L-sized, especially financial resource. They do not position themselves to become leaders in this industry. So they do not required much on high technical support as it may leads to higher cost.

Table 4.4 Criteria ranking between medium and large-sized manufacturers

Sub-criteria	Overall		Medium-sized		Large-sized	
	Weight	Rank	Weight	Rank	Weight	Rank
Price	0.0869	2	0.0858	1	0.0882	2
Other cost	0.0751	8	0.0722	10	0.0784	5
Lead time	0.0910	1	0.0851	2	0.0981	1
On-time delivery	0.0750	9	0.0739	9	0.0764	7
Product quality and reliability	0.0786	5	0.0822	3	0.0744	8
Continuous improvement ability	0.0806	3	0.0809	4	0.0804	4
Capacity and flexibility	0.0791	4	0.0800	5	0.0780	6
Technical capability	0.0766	6	0.0719	11	0.0822	3
Collaborative development	0.0678	13	0.0716	12	0.0632	13
Green manufacturing	0.0711	11	0.0756	7	0.0657	12
Green product and design	0.0690	12	0.0674	13	0.0710	11
Natural risk	0.0755	7	0.0785	6	0.0718	10
Human risk	0.0736	10	0.0748	8	0.0721	9

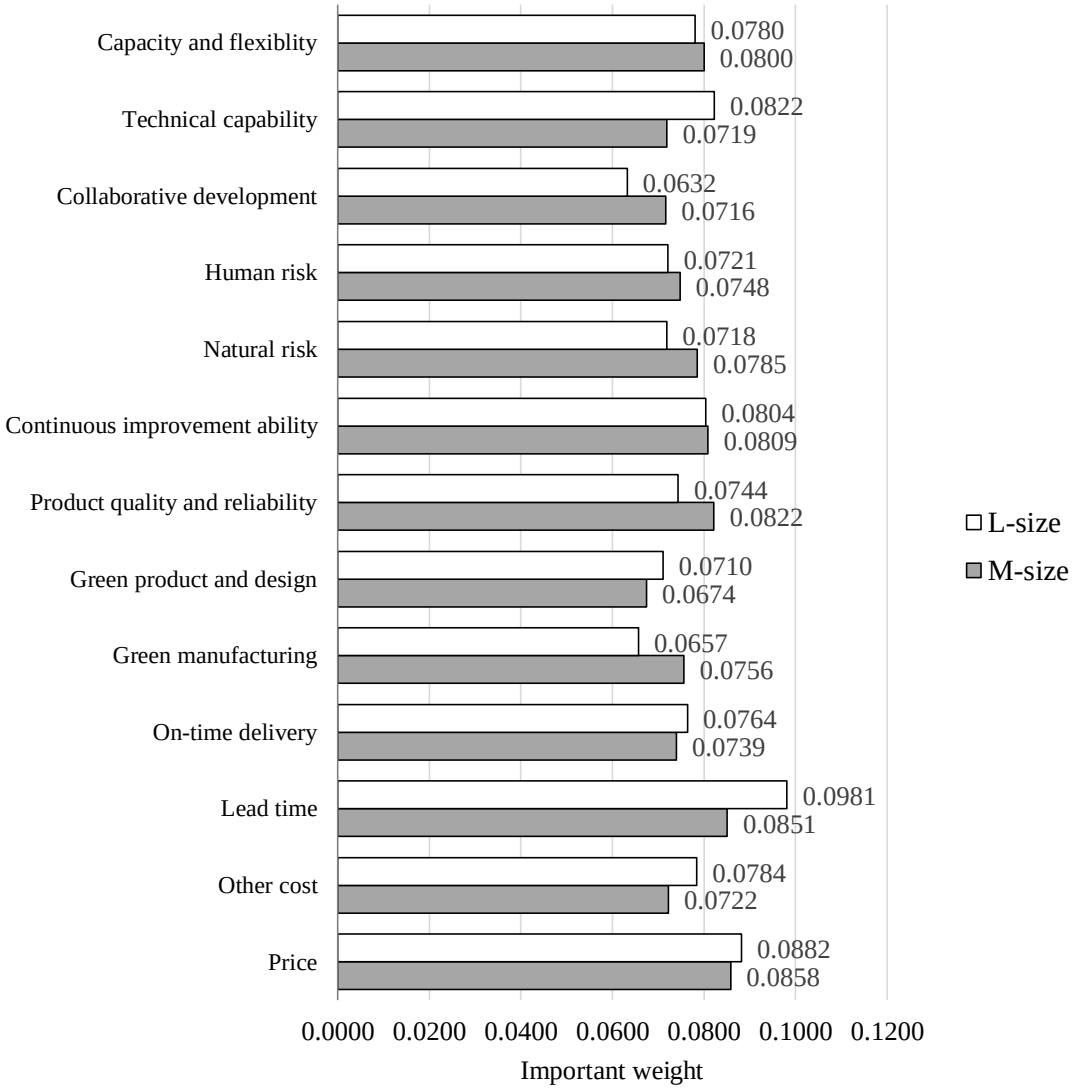


Figure 4.4 Relative important weight classified by size of company

4.2.3 Criteria Importance Classified by Types of Company

Important weight distinguished by types of company are presented in Table 4.5. The results show that, obviously types of company affects to criteria concerning as their criteria ranked by important weight are different. For Thai ownership company, technical capability is the most concerning criteria, follows by lead time, capacity and flexibility, and price. Joint company between Thai and foreign company concerns most about natural risk, follows by lead time, continuous improvement ability, and price.

Whereas price is the most important criteria of foreign company, follows by, lead time, continuous improvement ability, and other cost. All the ranks are shown in Table 4.5.

Table 4.5 Overall criteria ranking classified by types of company

Sub-criteria	Thai company		Joint company		Foreign company	
	Weight	Rank	Weight	Rank	Weight	Rank
Price	0.0834	4	0.0827	4	0.0916	1
Other cost	0.0665	11	0.0734	9	0.0807	4
Lead time	0.0917	2	0.0909	2	0.0907	2
On-time delivery	0.0834	4	0.0761	7	0.0698	11
Product quality and reliability	0.0782	6	0.0778	6	0.0794	7
Continuous improvement ability	0.0747	8	0.0838	3	0.0818	3
Capacity and flexibility	0.0876	3	0.0716	10	0.0795	6
Technical capability	0.0918	1	0.0593	13	0.0797	5
Collaborative development	0.0546	13	0.0740	8	0.0709	9
Green manufacturing	0.0736	9	0.0656	12	0.0734	8
Green product and design	0.0724	10	0.0704	11	0.0663	12
Natural risk	0.0650	12	0.0923	1	0.0701	10
Human risk	0.0770	7	0.0820	5	0.0662	13

The rankings of criteria are different between medium-sized and large-sized company due to their characteristics and constrains, such as resource, capability, know-how, etc. The results compare between medium-sized and large-sized company categorized by types of company are showed in Figure 4.5-4.7.

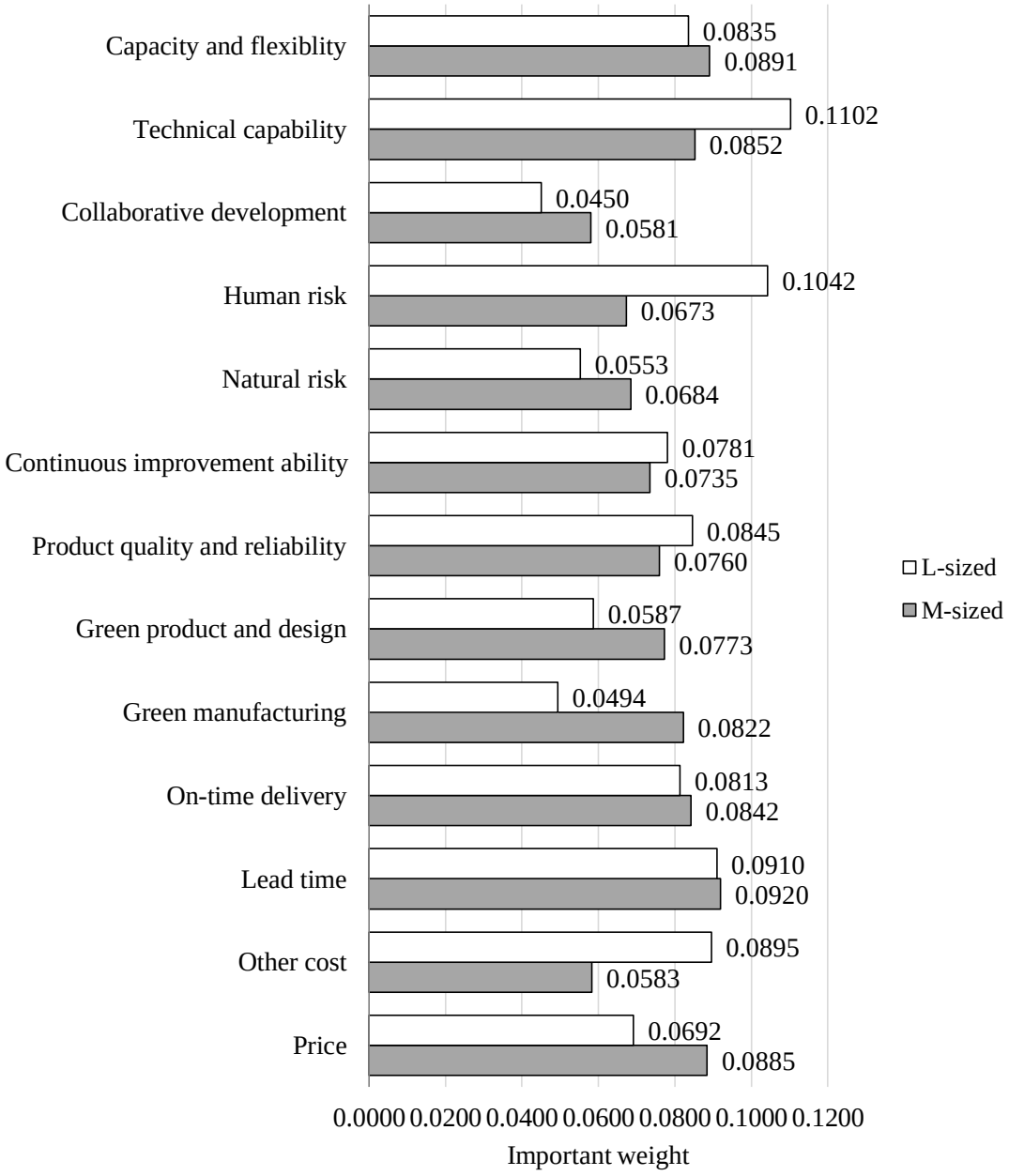


Figure 4.5 Relative important weight of Thai ownership company classified by size of company

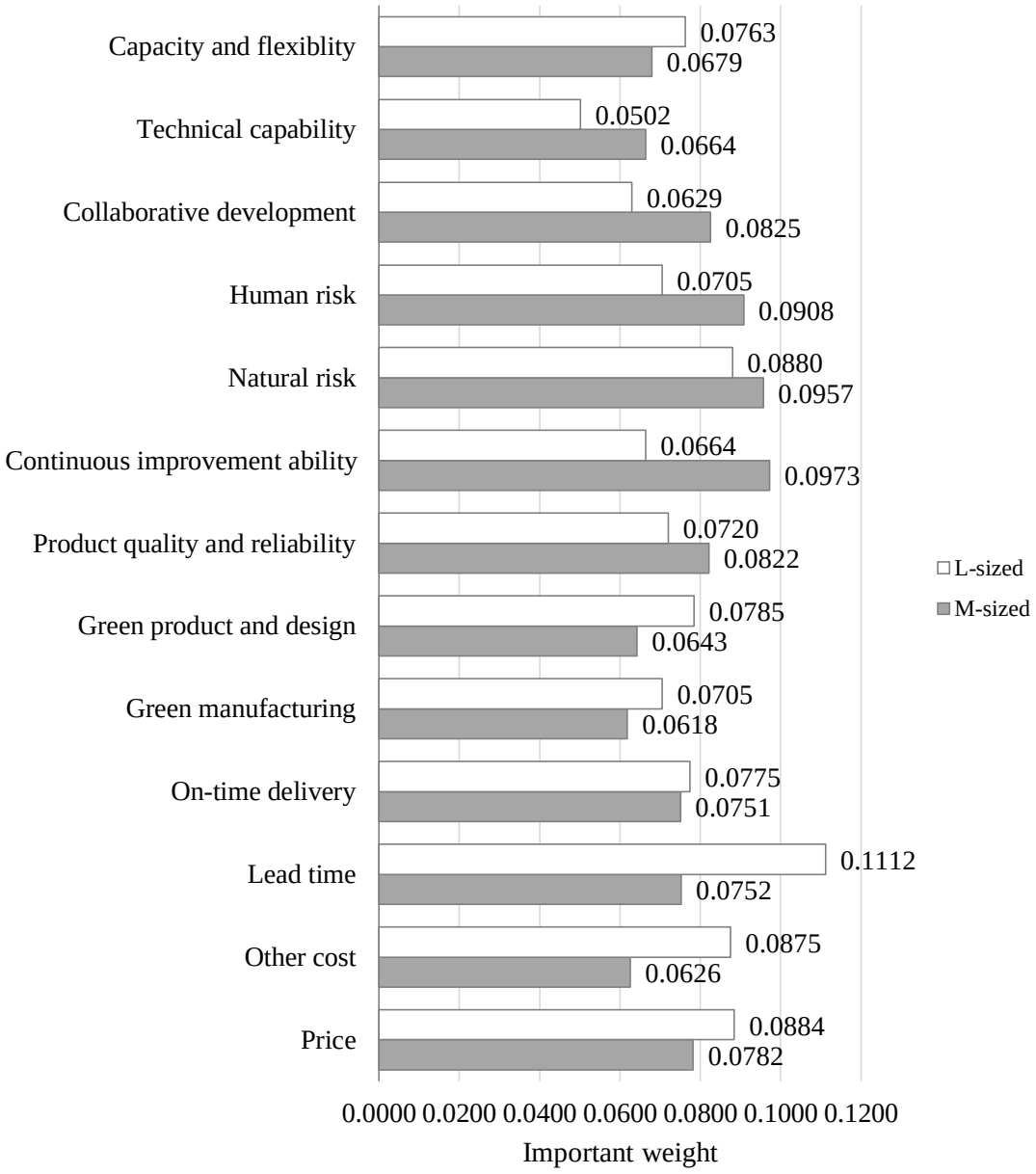


Figure 4.6 Important weight of joint company between thai and foreign classified by company size

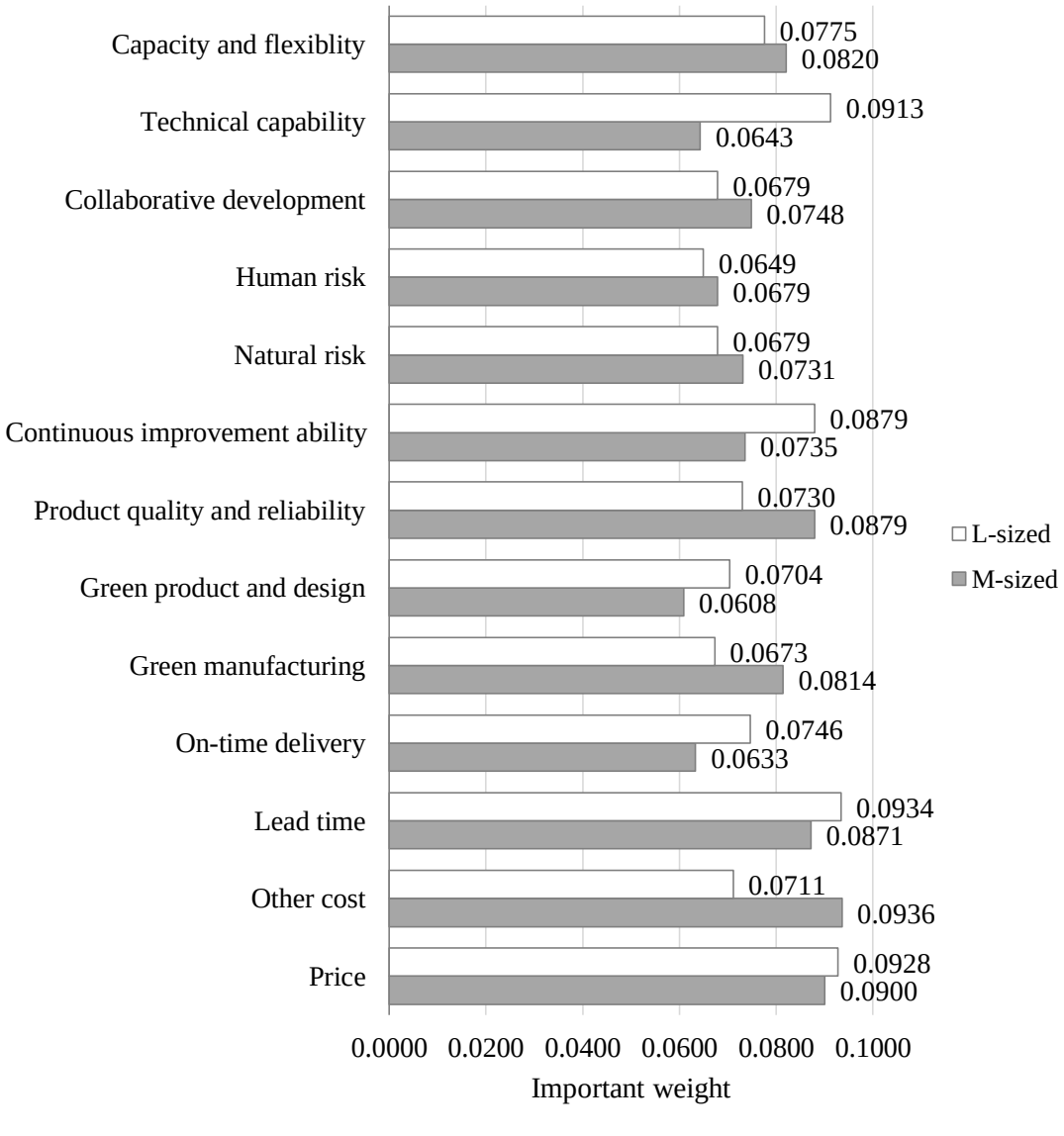


Figure 4.7 Relative important weight of foreign company classified by size of company

4.3 Performance Evaluating

In questionnaire, respondents are asking to select their current suppliers. One is the first priority supplier which means the most favorable supplier who is the first priority to be selected. Another one is the alternative supplier who is less priority to be selected, namely, less priority supplier. The respondents are asked to evaluate performance based on real data or satisfaction score for objective criteria and subjective criteria, respectively. The types of criteria are shown in Table 4.6.

As explanation in Chapter 3 that the performance in this research is measured into 3 characteristics. Therefore in each criteria, respondent are asked to evaluate performance of supplier in order to obtain the value of mean, SD, and skewness. But to obtain the value of SD and skewness is not easy as mentioned earlier. Threrefore, the question in questionnaire is not directly asked respondents to provide the value of SD and skewness but after the survey was done, the results from questionnaire are transformed into 3 perspectives, which are, mean, standard deviation and skewness using equations showed in chapter 3.

Table 4.6 Types of criteria

Type	Sub-criteria	Index
Objective	Price	Actual price
	Other cost	Actual cost
	Lead time	Actual lead time
	On-time delivery	% On-time delivery
	Product quality and reliability	% Return rate
Subjective	Continuous improvement ability	Satisfaction score
	Capacity and flexibility	
	Technical capability	
	Collaborative development	
	Green manufacturing	
	Green product and design	
	Natural risk	
	Human risk	

4.3.1 Coefficient of Variation

The overall results of CV (Coefficient of Variation) categorized by size of company is presented in Table 4.7. From the results of performance evaluated by buying manufacturers, although we indicated that in this research performance perspective is defined into 3 characteristics, 1) efficiency measured by mean, 2) stability measured by standard deviation, and 3) tendency measured by skewness, only 2 indexes are shown in Table 4.7. CV means coefficient of variation which represents the ratio between standard deviation to the mean. Hence this statistical measure

combines the perspective of mean and standard deviation into one. The lower of CV means the better supplier.

Table 4. 7 Results of performance evaluation: Coefficient of Variation (CV)

Main criteria	Sub-criteria	Supplier Category					
		First priority			Less priority		
		Overall	M	L	Overall	M	L
Cost	Price	0.0316	0.0320	0.0311	0.0401	0.0415	0.0383
	Other cost	0.0679	0.0768	0.0549	0.0790	0.0965	0.0479
Delivery	Lead time	0.0616	0.0622	0.0608	0.0802	0.0851	0.0747
	On-time delivery	0.0248	0.0216	0.0284	0.0306	0.0308	0.0304
Quality	Product quality and reliability	0.2751	0.2276	0.3171	0.2889	0.3168	0.2564
	Continuous improvement ability	0.0328	0.0329	0.0327	0.0344	0.0325	0.0367
Supplier condition and relationship	Capacity and flexibility	0.0339	0.0352	0.0322	0.0436	0.0455	0.0412
	Technical capability	0.0362	0.0352	0.0372	0.0436	0.0453	0.0415
	Collaborative development	0.0376	0.0391	0.0358	0.0546	0.0565	0.0520
Green supplier	Green manufacturing	0.0275	0.0294	0.0254	0.0312	0.0315	0.0309
	Green product and design	0.0335	0.0336	0.0334	0.0285	0.0292	0.0276
Supplier risk	Natural risk	0.0412	0.0426	0.0397	0.0685	0.0717	0.0643
	Human risk	0.0745	0.0760	0.0727	0.0580	0.0617	0.0529

Criterion with highest stability and low risk (lowest CV) is on time delivery with CV of 0.024, follows by product quality and reliability, green manufacturing, price, and continuous improvement ability, respectively. The lowest stability with high risk performance of supplier (highest CV) is product quality and reliability with CV of 0.2751. Not every favorable suppliers of both sized manufacturers have lower CV than unfavorable suppliers for all criteria. For medium-sized manufacturers, there are 3 criteria which CV of first priority suppliers are higher than less priority suppliers, that are, green product and design, natural risk, and human risk. For large-sized

manufacturers, there are 5 criteria, which are, other cost, product quality and reliability, green product and design, natural risk, and human risk. However, the influence of these criteria are not much high compared with criteria which first priority suppliers have lower CV judged by their important weight.

In the next section, each main criteria will be discussed one by one based on the results in Table 4.7.

1. Cost: The first sub-criteria to discuss in this dimension is price. For both of medium and large-sized buyers, first priority and less priority suppliers have similar variation, i.e. both CV are close to each other. However, less priority suppliers have a little higher CV. This means, based on buyers' opinion, first priority supplier should provide more stable performance. Also first priority suppliers of large-sized company seems to have more stable, i.e. less variation, performance than less priority suppliers. Compare to price, other cost is more unstable than price. Because of many external factors affecting to other cost, it is hard for supplier to control these factors, such as, fuel surcharge, foreign exchange rate which fluctuated throughout the time. First priority suppliers of medium-sized have lower variation than less priority suppliers while suppliers of large-sized have a little bit higher variation. However, the overall CV shows that first priority suppliers have lower CV, i.e. higher stability than less priority suppliers.

2. Delivery: Despite many criteria involved in supplier selection, we cannot deny that one of the most important criteria at all time is lead time, especially in current business era of high responsive. From Table 4.7, it can be seen that first priofity supplier has lower CV than less priority supplier. This means buyers would select supplier with higher stability and low variance because it is easier to make a schedule plan. This is also true with on-time delivery. Even there is not much different between CV of first priority and less prioity suppliers, nevertheless, first priority suppliers have lower CV. Also, the results show that on-time delivery seems to have lower variance and higher stability than lead time as its CV is lower.

3. Quality: For the sub-criteria of product quality and reliability, CV of first priority and less priority supplier are not much different compared with sub-criteria of continuous improvement ability. Even first priority suppliers of medium-sized

manufacturers have a little higher CV than less priority suppliers, 0.0329 and 0.0325, respectively, the difference is very narrow so it can be conclude that their CV is not different. First priority suppliers of large-sized manufacturers have higher variation, i.e. CV of product quality and reliability than less priority suppliers. But this sub-criteria has merely moderate importance based on the judgment of large-sized buyers as important weight shown in Table 4.4. Also their CV is not much different.

4. Supplier Condition and Relationship: This main criteria is the most important criteria which has highest weight important compared with other main criteria. For all 3 sub-criteria in this dimension, although first priority and less priority suppliers have not much different CV, it is obvious that les priority suppliers of both sizes still have higher CV than first priority suppliesrs.

5. Green Supplier: For green manufacturing, the result is in accordance with the assumption that first priority suppliers should be more stable than less priority suppliers. However, their CV are not much different. Differ from green manufacturing, for green product and design, first priority suppliers have a little higher value of CV than less priority suppliers. One of the main reason is the insignificance of green supplier criteria. From the result of criteria important weight, green manufacturing and green product and design are in eleventh and twelfth rank, respectively. This induces suppliers not to regard much with improving green efficiency because buyers have low concern about this criteria.

6. Supplier Risk: From Table 4.7, both of medium and large-sized manufacturers have higher CV on first priority suppliers rather than less priority suppliers in criteria of human risk. But compared with natural risk, the difference of CV for natural risk is much higher with lower CV on first priority suppliers. Therefore, we may say that, first priority suppliers tend to have higher stability than less priority suppliers for the overall result of this main criteria. However, human risk seems to have more variation than natural risk for both sizes.

In summary, suppliers of medium-sized manufacturers tend to have higher CV than large-sized manufactures. This is because of medium-sized buyers are likely to have weaker power compared with large-sized buyers. Due to their quantity purchased, resources and financial statement, they have fewer options than large buyers. Therefore,

even their first priority suppliers tends to have lower stability compared with large-sized companies' suppliers.

4.3.2 Skewness

Based on the direction of skewness, there are 2 types of performance. One is performance with preference of negative skewness or the higher of performance index, the better efficiency, such as %on-time delivery. In this case, buyers would expect greater value of performance or prefer suppliers who have left-skewed performance. Conversely, another one is performance with preference of positive skewness or the lower of performance index, the better efficiency, such as cost and lead time. In this case, buyers would expect lower value of performance or prefer right-skewed rather than left-skewed performance. According to set of criteria in this research, each type of skewness preference is shown as followings:

Type I: Positive skewness preference or right-skewed performance: Buyers prefer lower value of performance than expectation. In other words, lower value means better performance. There are 4 criteria in this type, namely, price, other cost, lead time, and product quality and reliability.

Type II: Negative skewness preference or left-skewed performance: Buyers prefer higher value of performance than expectation which means greater value, better performance. The rest of criteria are in this type, which are, on-time delivery, continuous improvement ability, capacity and flexibility, technical capability, collaborative development, green manufacturing, green product and design, natural risk, human risk.

Table 4.8 presents the result of skewness evaluation. For type I performance, 3 of 4 criteria in this type have skewed performance as expected. For example, criteria of lead time, first priority suppliers for both of medium and large-sized have shorter lead time than buyers' expectation, i.e., average lead time as their skewness is positive value. This means in buyers' perspective, favorable supplier is supplier who is able to provide product in shorter time than promised lead time. In contrast to first priority suppliers, suppliers with less priority have left-skewed performance which means most likely they provide product with longer lead time than promised lead time.

Table 4.8 Results of performance evaluation: Skewness

Main criteria	Sub-criteria	Supplier Category					
		First priority			Less priority		
		Overall	M	L	Overall	M	L
Cost	Price	-0.2866	-0.3767	-0.1790	-0.3779	-0.4357	-0.3088
	Other cost	1.1210	1.0338	1.2251	-0.6336	-0.7919	-0.4446
Delivery	Lead time	0.8788	0.8033	0.9690	-0.7569	-0.8645	-0.6284
	On-time delivery	-0.8436	-1.0169	-0.6369	0.9133	0.8870	0.9447
Quality	Product quality and reliability	0.9953	1.1871	0.7664	-0.7999	-0.7074	-0.9103
	Continuous improvement ability	-0.4440	-0.5413	-0.3279	0.8877	1.0294	0.7186
Supplier condition and relationship	Capacity and flexibility	-0.5426	-0.5983	-0.4762	1.0451	0.9604	1.1463
	Technical capability	-0.9720	-1.0004	-0.9381	0.4059	0.4432	0.3613
	Collaborative development	-0.4901	-0.5606	-0.4059	0.4112	0.3052	0.5377
Green supplier	Green manufacturing	-0.3786	-0.2074	-0.5829	0.3865	0.5175	0.2303
	Green product and design	-0.3601	-0.1857	-0.5682	0.4742	0.5593	0.3726
Supplier risk	Natural risk	-0.5624	-0.5235	-0.6089	0.4820	0.6439	0.2887
	Human risk	-0.8261	-0.7708	-0.8922	0.5045	0.5451	0.4560

In opposed to type I performance, type II performance should skew to the left. All of first priority suppliers of medium and large-sized manufacturers have left-skewed performance as their skewness are negative value. This implies that first priority suppliers provide higher performance than buyers' expectation. In contrast to first priority suppliers, less priority suppliers of both size have right-skewed performance which means, molt likely, their actual performances tend to be lower than expected. For example, criteria of continuous performance. Supposed that the average performance is 80 score, but most likely they performance and get lower score than 80, for example, mostly their score is around 70 score. In this case, this supplier tends to have lower performance than average performance. Its performance would skew to the right with positive skewness value.

Each main criteria will be discussed one by one based on the results in Table 4.8 as the following parts:

1. Cost: Both of medium and large-sized manufacturers have skewed performance of other cost as expected. Performance of first supplier skew to the right (positive value), while performance of less priority suppliers skew to the left (negative value). This makes the overall skewness of other cost skewed to the same direction for both types of suppliers. But this is not applied for price which both of good and bad suppliers have right-skewed performance. That means both of them seems to have higher price than average price but skewness value is quite low which will be discussed again in the next section.

2. Delivery: Lead time and on-time delivery have skewed performance for both of first priority and less priority suppliers to the expected direction. Compare to other sub-criteria outside this dimension, delivery has highest skewed performance as their overall skewness in greater than other criteria. Being the second rank of dimension, this implies that skewness has immense effect on distinguishing between favorable and unfavorable suppliers.

3. Quality: Good suppliers of medium-sized manufacturers tend to have higher skewed performance than large-sized manufacturers as their absolute value of skewness is greater than large-sized. In the other hand, less priority suppliers of large-sized manufacturers have higher skewed performance than medium-sized. To compare between 2 sub-criteria, performance of continuous improvement ability of good suppliers have more slightly skewed than product quality and reliability.

4. Supplier Condition and Relationship: For first priority suppliers, technical capability have highest skewed compared with other sub-criteria in this group. This is because of high technology required in this industry type. In order to become favorable suppliers, high competence and good know-how is necessary. For less priority suppliers, the highest skewed performance is capacity and flexibility which means severely unfavorable suppliers are suppliers who cannot provide the quick response to changes for both of quantity and design which is different from today's competitive environment and end-customer satisfaction. Mostly, suppliers' performance of medium-sized manufacturers are more skewed than large-sized.

5. Green Supplier: Even the results of skewness show that performance of sub-criteria of green supplier are skewed to the expected direction, judged by the sign of skewness, but their value is low compared to other criteria. In other words, performance tendency between first priority and less priority suppliers in this criteria is scarcely different. But compare to other criteria, green manufacturing and green product and design have lowest important weight than other criteria. Therefore, suppliers are not concern much to improve their efficiency of these criteria.

6. Supplier Risk: First priority suppliers of large-sized manufacturers seems to have more tendency to improve their performance than suppliers of medium-sized as their skewness value is greater than suppliers of medium-sized manufacturers. In contrary, less priority suppliers of medium-sized manufacturers are more skewed or tend to have lower performance than expected. Also their performance are skewed more than large-sized manufacturers. First priority suppliers seem to have ability to deal with errors and uncertainties event which are caused from human rather than natural risk. Because to prevent errors and uncertainties done by human is easier to correct or control the situations. Good suppliers should foresee some uncertainties and plan in advance in case any unexpected circumstances occur.

In summary, both types of suppliers have skewed performance to the expected direction for most of the criteria. While first priority suppliers perform better than expected, less priority suppliers perform worse. However, the skewness effect will be in-depth discussed in the next section.

4.4 Skewness Effect

In order to discuss in-depth about skewness effect on suppliers' performance, the level of skewness based on its skewness value are needed to be defined. (Bulmer, 1979) interpreted skewness level based on skewness value as following scale:

$Sk \leq -1$ or $Sk \geq 1$: Highly skew

$-1 < Sk \leq -1/2$ or $1/2 \leq Sk < 1$: Moderately skew

$-1/2 < Sk < 1/2$: Approximately symmetrical

From the result of skewness performance in Table 4.8 combines with the rule of skewness from Bulmer, skewness effect is shown in Table 4.9. There are three notations in the table. Each notation is defined as following meanings:

"0" represents no effects of skewness (absolute value of skewness is less than 0.5)

"+" represents having at least moderately effect of positive skewness (skewness value is greater than 0.5)

"-" represents having at least moderately effect of negative skewness (skewness value is less than -0.5)

With 13 sub-criteria, 2 sizes of manufacturers, and 2 types of suppliers, there are 13x2x2 = 52 to-be skewness results as shown in Table 4.9. Based on Bulmer's skewness rule, most of the results are skewed to the expected direction but some performances are not skewed as expected, especially less priority suppliers of large-sized manufacturers. This implicitly reverberates the circumstance that large buyers have power over suppliers. Large-sized buyers have large quantity order, therefore they are able to force suppliers in order to retain their level of efficiency. Even less priority suppliers have to maintain their performance.

Table 4.9 Skewness effect based on Bulmer's rule (1979)

Main criteria	Sub-criteria	Supplier Category					
		First priority			Less priority		
		expected direction	M	L	expected direction	M	L
Cost	Price	+	0	0	-	0	0
	Other cost	+	+	+	-	-	0
Delivery	Lead time	+	+	+	-	-	-
	On-time delivery	-	-	-	+	+	+
Quality	Product quality and reliability	+	+	+	-	-	-
	Continuous improvement ability	-	-	0	+	+	+
Supplier condition and relationship	Capacity and flexibility	-	-	0	+	+	+
	Technical capability	-	-	-	+	0	0
	Collaborative development	-	-	0	+	0	+
Green supplier	Green manufacturing	-	0	-	+	+	0
	Green product and design	-	0	-	+	+	0
Supplier risk	Natural risk	-	-	-	+	+	0
	Human risk	-	-	-	+	+	0

There is no criteria which performance is skewed in the opposite direction as the assumptions, only no skewed performance emerge for some criteria. However, in order to deeply discuss about the real effect of skewness, performance of first priority and less priority suppliers in the same criteria will be considered altogether. If both of them have skewed performance, it is clearly that skewness strongly affect supplier performance. For each criterion, if either first priority or less priority supplier has skewed performance, then it can also say that skewness effect exists. Only if no skewness for both types of suppliers emerges, then there is no effect of skewness at all. Therefore, all criteria performance are classified into groups based on the rule of skewness as mentioned earlier. The skewness effect of each criterion are summarized and shown in Table 4.10. The meaning of each mark is defined as below:

++ highly effect: both of first priority and less priority suppliers have at least moderately skewed performance as expected

+ moderately effect: either first priority or less priority suppliers have at least moderately skewed performance as expected

0 no effect: neither first priority nor less priority suppliers have skewed performance as expected

Table 4.10 Summary of skewness effect

Rank of important weight	Sub-criteria	Skewness effect		
		Overall	M	L
1	Lead time	++	++	++
2	Price	0	0	0
3	Continuous improvement ability	+	++	+
4	Capacity and flexibility	++	++	+
5	Product quality and reliability	++	++	++
6	Technical capability	+	+	+
7	Natural risk	+	++	+
8	Other cost	++	++	+
9	On-time delivery	++	++	++
10	Human risk	++	++	+
11	Green manufacturing	0	+	+
12	Green product and design	0	+	+
13	Collaborative development	0	+	+

Looking at the result of overall skewness effect in Table 4.10, there is 4 sub-criteria which have no skewness effect. But distinguishing between the two sizes of manufacturing, the result shows that more skewness effect has been emerged. This is because the difference characteristics between two sizes. In some criteria its performance is skewed to the different direction. For example, green manufacturing, less priority suppliers of medium-sized have right skewed performance (positive

skewness), while first priority suppliers of large-sized manufacturers have left skewed performance (negative skewness). Combining both sizes deducted their opposite effect of skewness. Therefore, the overall result shows no effect of skewness at all. Hence, to discuss on skewness effect, the classification between sizes of company is necessary.

However, the level of skewness effect is different between both sizes. Figure 4.8 and 4.9 present the comparison of skewness level on each size of manufacturer. Skewness effect plays stronger role on medium-sized manufacturers than large-sized manufacturers. As presented in Figure 4.8, more than half of sup-criteria of medium-sized manufacturers have high skewness effect. Different from medium-sized, more than half of sub-criteria of large-sized company have moderate skewness effect as presented in Figure 4.9.

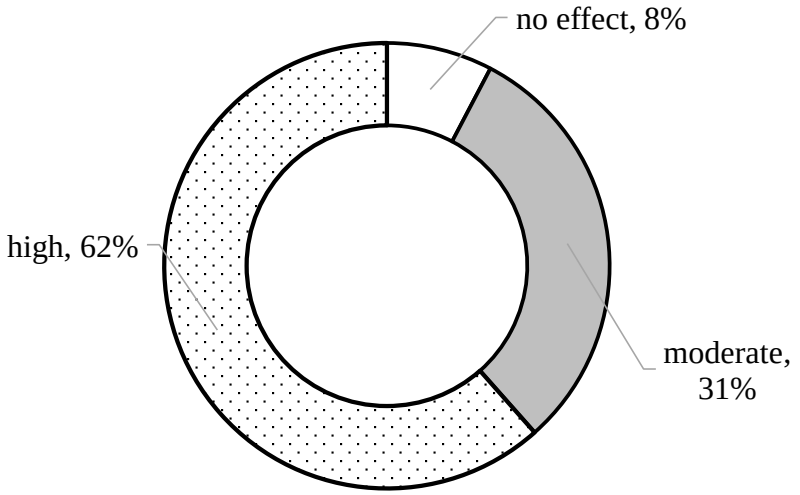


Figure 4.8 Ratio of skewness effect of medium-sized manufacturers

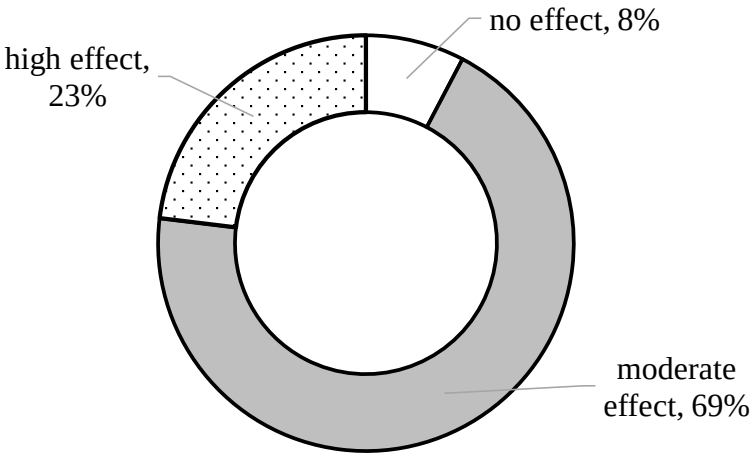


Figure 4.9 Ratio of skewness effect of large-sized manufacturers

	No effect	moderate	high
L	• Price (2)	• Conti. imp. ability (4) • Capacity and flexibility (6) • Tech.capability (3) • Natural risk (10) • Other cost (5) • Human risk (9) • Green manu. (12) • Green prod. & design (11) • Collab. devel. (13)	• Lead time (1) • On-time delivery (7) • Product qual, & reli. (8)
M	• Price (1)	• Tech.capability (11) • Green manu. (7) • Green prod. & design (13) • Collab. devel. (12)	• Lead time (2) • Conti. imp. ability (4) • Capacity and flexibility (5) • Product qual, & reli. (3) • Natural risk (6) • Other cost (10) • On-time delivery (9) • Human risk (8)

Level of effect

Figure 4.10 Level of skewness effect

The summary of skewness effect in Table 4.10 is transformed into graph in order to give a clearer picture of the level of skewness based on buyers' company size and presented in Figure 4.10. The number in parenthesis is the rank of important weight of each criterion. The results can be classified into 3 groups.

1. Performance with highly effect of skewness (++): There are 3 performances which have highly effect of skewness on suppliers' performance of both large and medium-sized manufacturers. That is, lead time, on-time delivery, and product quality and reliability. Performances of first priority suppliers and less priority suppliers are extremely different due to their different direction of skewness. For medium-sized manufacturers, it tends to have greater difference among suppliers and easier to distinguish between first priority and less priority supplier more than large-sized manufacturers as the number of highly skewed sub-criteria is greater. Because large-sized buyers have greater choices of suppliers by reason of their sufficient resources and power. Hence, there is small gap between first priority and less priority suppliers than medium-sized buyers who have limited resource and lower power.

One interesting issue is, there are 2 sub-criterion from 3 key performance measurement in manufacturing, QCD (Quality, Cost and Delivery), which are highly skewed. That means these key measurements are able to distinguish between good and bad suppliers very well.

2. Performance with moderately effect of skewness (+): For large-sized buyers, there are 9 sub-criteria in this group, which are, continuous improvement ability, capacity and flexibility , technical capability , natural risk, other cost , human risk, green manufacturing, green product and design, and collaborative development. Medium-sized buyers have only 4 sub-criteria, which are, technical capability, green manufacturing, green product and design, and collaborative development. Among all 4 moderate skewed performance of medium-sized manufacturers, the ratio of having bad skewed to having good skewed performance is 50% to 50% (2 sub-criteria of each), while the ratio of large-sized manufacturers is 33% to 67%. That means suppliers of large-sized buyers have more skewed performance on first priority suppliers rather than less priority suppliers. In other words, to be judged as unfavorable suppliers, it is not essential to have performance skewed to the inappropriate direction. But in order to be

judged as first priority suppliers, besides consideration of average and variance of performance, suppliers should have performance skewed to the expected direction.

Figure 4.11 presents the list of moderate skewed performances as well as their size of company.

	Good skewed	Bad skewed
M	• Technical capability • Collaborative development	• Green manufacturing • Green product and design
L	• Technical capability • Green manufacturing • Green product and design • Collaborative development	• Continuous improvement ability • Capacity and flexibility

Figure 4.11 Moderate sub-criteria of each size of buyers and types of suppliers

It is no doubt that large-sized manufacturers have sufficient resources more than medium-sized. So they have ability to rapidly adjust themselves to cope with changing in terms of design, process or quantity. Also with their knowledge and technology, they do not rely much on suppliers. Therefore, first priority supplier in the perspective of large-sized companies are not required to have tendency to improve their performance in the criteria of continuous improvement ability, capacity and flexibility, and collaborative development. But this is different from technical capability criteria. First priority suppliers of both medium and large-sized manufacturers have skewed performance, while less priority suppliers have no skewness. This reflects that technology is important issue for electronics industry, especially in the age that technology is developed so fast. Hence, even unfavorable suppliers need to maintain

their performances to meet buyers' expectation. Otherwise they would not survived in this industry.

Both of sub-criteria in green supplier, first priority suppliers of large-sized companies have tendency to have higher performance than expectation since their performances are skewed to the expected direction, while first priority suppliers of medium-sized companies have no tendency since their performance have no skew. Even green issue has become world issue, but for Thai manufacturers, the issue has just become mattered for few years, many of them are not still concern much about green criteria as their important weight are ranked in the bottom three. This leads to the thought of unnecessary to pay attention to improve green efficiency, especially for medium-sized buyers. However, large-sized companies seem to concern on environmental issues more than medium-sized. Therefore, first prioity suppliers of large-sized must have skewed performances as shown in the result. In contrast, less priority suppliers of medium-sized companies have skewed performance while large-sized companies' suppliers have no skew.

One interesting issue is unfavorable suppliers' performance of other cost criteria for large-sized buyers are not skewed as we expected. Because of buyers' power over suppliers, buyers can forced suppliers to monitor their performances avoiding failing to meet buyers' expectation even unfavorable suppliers.

3. Performance with no effect of skewness (0): Most of criteria have fluctuated performance with tendency to differ from average efficiency, only price has no skewness effect on both of first priority and less priority suppliers of M and L-sized companies. This is because of the actual price cannot be much varied as it depends on acceptable price or the contract made by both of buyer and supplier. However, other cost which is in the same main criteria of cost is significantly skewed as shown in the result, so we cannot deny the effect of skewness on cost performance on buyer decision at all.

In summary, it appears that, in perspective of performance tendency, first priority suppliers (supplier who performs well and be the first priority to be selected) and less priority suppliers (suppliers who has lowest historical performance and be the last choice to be selected) are different. Upon the hypothesis of skewness effect, either

performance skewness of first priority or less priority suppliers can support the existence of skewness effect.

As aforementioned, performance perspective in this research can be classified into 3 perspectives:

1. Performance efficiency measured by mean
2. Performance stability measured by standard deviation
3. Performance tendency measured by skewness

Apparently, skewness plays important role on suppliers' performance but to compare skewness effect with other performance perspectives, statistical hypothesis testing is applied in order to give guidance to suppliers of which perspective should be improved. The paired sample t-Test is used to compare the difference of performance evaluating between first priority and less priority suppliers for each criteria in each perspective. The hypothesis are:

H_0: performance efficiency of first priority and less priority suppliers are equal

H_1: performance efficiency of first priority and less priority suppliers are different

H_0: performance stability of first priority and less priority suppliers are equal

H_1: performance stability of first priority and less priority suppliers are different

H_0: performance tendency of first priority and less priority suppliers are equal

H_1: performance tendency of first priority and less priority suppliers are different

With the significance level equal to 0.05, the results are shown in Table 4.11 ranked by importance weight. This table summarizes the effect of each performance

perspective on buyer's decision which provides the Guidance of which perspective should be improved. The tick mark refers to accepting the null hypothesis while the cross mark refers to rejecting the null hypothesis.

Table 4.11 Guidance of which perspective should be improved

Rank of important weight	Sub-criteria	Performance perspective					
		M-sized buyers			L-sized buyers		
		Mean	SD	Sk	Mean	SD	Sk
1	Lead time	✓	✓	✓	✓	✓	✓
2	Price	×	✓	×	✓	✓	×
3	Continuous improvement ability	×	×	✓	✓	×	✓
4	Capacity and flexibility	✓	×	✓	✓	×	✓
5	Product quality and reliability	✓	✓	✓	✓	✓	✓
6	Technical capability	×	✓	✓	×	✓	✓
7	Natural risk	✓	✓	✓	✓	✓	✓
8	Other cost	✓	✓	✓	✓	×	✓
9	On-time delivery	✓	✓	✓	✓	×	✓
10	Human risk	✓	✓	✓	×	✓	✓
11	Green manufacturing	×	×	✓	×	✓	✓
12	Green product and design	×	×	✓	×	✓	✓
13	Collaborative development	✓	✓	✓	✓	×	✓

To interpret the results shown in Table 4.11, here is the example:

- Criteria of lead time: Both of M and L-sized manufacturers, all performance perspectives have effects on buyer's decision, therefore, suppliers should concern on improving their performance in all three perspectives rather than focusing on only average performance.

- Continuous improvement ability: For M-sized buyers, the result shows that focusing on only mean and SD cannot distinguish between first priority and less priority suppliers, since there are no difference between them. In fact, but buyers use skewness to determine which supplier should be the first priority to be selected.

For both of medium and large-sized manufacturers, skewness plays greater role on performance than other perspectives. As presented in Figure 4.11 and 4.12, the number of sub-criteria which can be used to distinguish between first priority and less priority suppliers of skewness is greater than other perspectives. In other words, only price cannot be discriminated by skewness. Therefore, Table 4.10 provides guidance of which perspective should be improved and concerned.

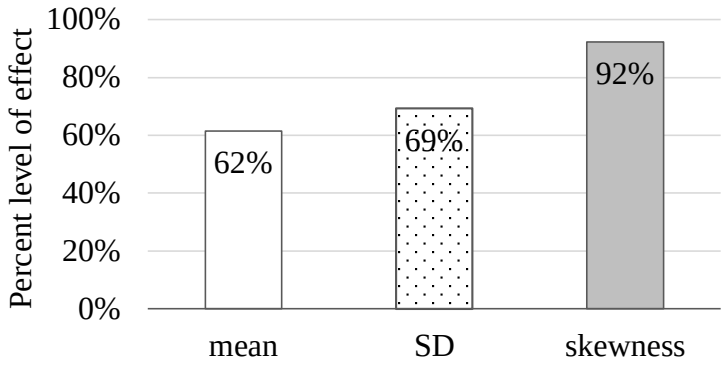


Figure 4.12 Comparison of perspective effect of medium-sized manufactures

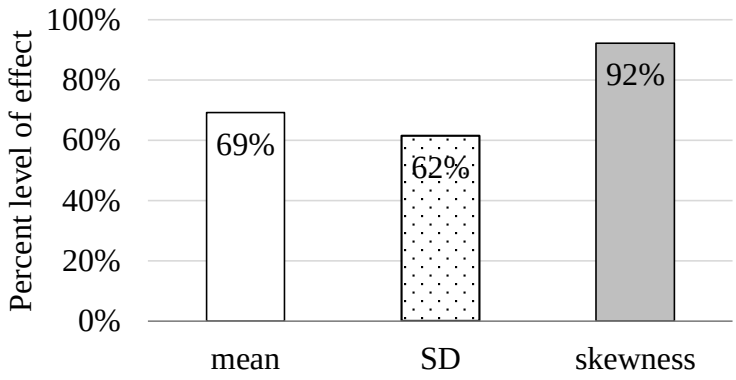


Figure 4.13 Comparison of perspective effect of large-sized manufactures

The interesting point obtaining is, for all criteria except price, only a perspective that matters to buyer's decision is skewness. So if suppliers would like to improve

themselves and become the first priority supplier, they should focus on their skewness rather than mean or variance. This concludes that skewness should not be neglect when making decision of supplier selecting and evaluating problem.

4.5 Developing Decision Matrix

The previous section proves that skewness between good and bad suppliers is different and play important roles when evaluating suppliers. Therefore, when buyers make a decision of which supplier should be selected, skewness should be included into the decision model. In order to develop decision matrix considering skewness, the concept of FMEA was modified. In FMEA, the risk level is measured by multiplying 3 combinations together, which are, severity, occurrence, and detectability. There is a researcher applied this concept in order to select supplier (P-S. Chen and Wu, 2013). It suggested to select supplier with lowest risk failure in order to avoid the possibility to be failure or the possibility that supplier would perform worse than expected. But in this research, it aims to measure the success ability, which means the possibility that supplier would perform better than expected. In this section, first the developing matrix is discussed, follows by validating matrix.

4.5.1 Developing Matrix by adpting FMEA

To select supplier by using FMEA method proposed by P.-S. Chen and Wu (2013), the objective is to select supplier who has lowest risk of failure. In contrary to select supplier based on risk perspective, this research aim to develop supplier selection method based on the potential success or the tendency of supplier to perform better than buyer's expectation. Therefore, the new approach to select suppliers called Success Mode Skewness Analysis (SMSA) is proposed. This approach is based on MVS concept which the assumption is supplier with greatest expected performance does not necessary be the best supplier but average performance, variance of performance and skewness should combine together in order to evaluate among suppliers.

The steps of SMSA method is shown in Figure 4.14. First, important weight is obtained from ANP approach. Then the combination of mean, standard deviation and skewness is determined in order to calculate MVS score.

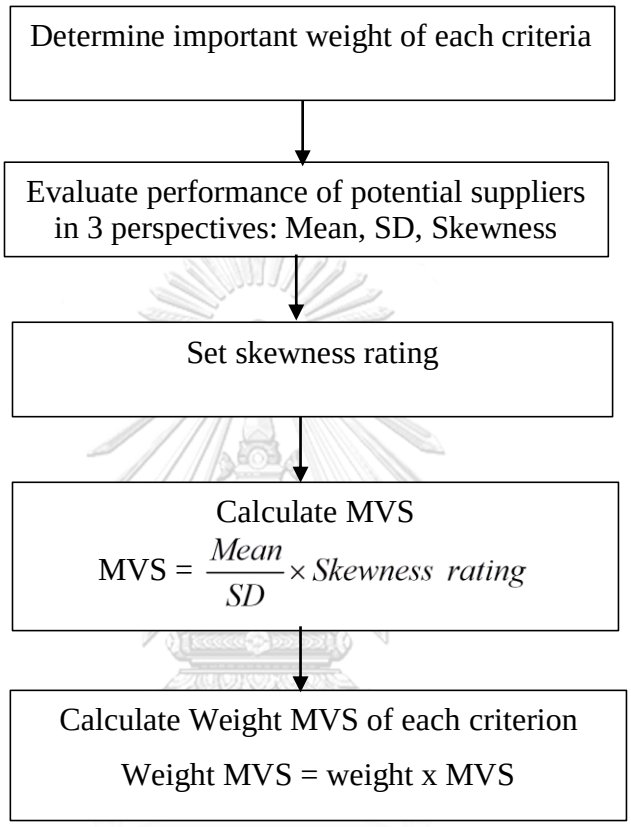


Figure 4.14 Steps of SMSA method for supplier selection

MVS score can be calculate using the following equation:

$$MVS = \frac{Mean}{SD} \times SR \tag{4.1}$$

Where Mean is average performance of supplier

SD is standard deviation

SR is skewness rating

From equation 4.1, MVS is calculated by multiplying the reciprocal of CV and skewness rating. Good supplier should have low CV and skewed performance to the expected direction. The ratio of mean to SD in the equation represents the reciprocal of CV which means the higher of this reciprocal, the better supplier. Hence, it can be interpreted that good suppliers should have high MVS score. But for skewness, the skewness value are not directly input to the equation but transformed into skewness rating based on Bulmer's rule of skewness but slightly adjusted the interpretation of skewness value. Figure 4.15 presents the comparison between Bulmer's rule and adjusted skewness rating for positive skewed performance.

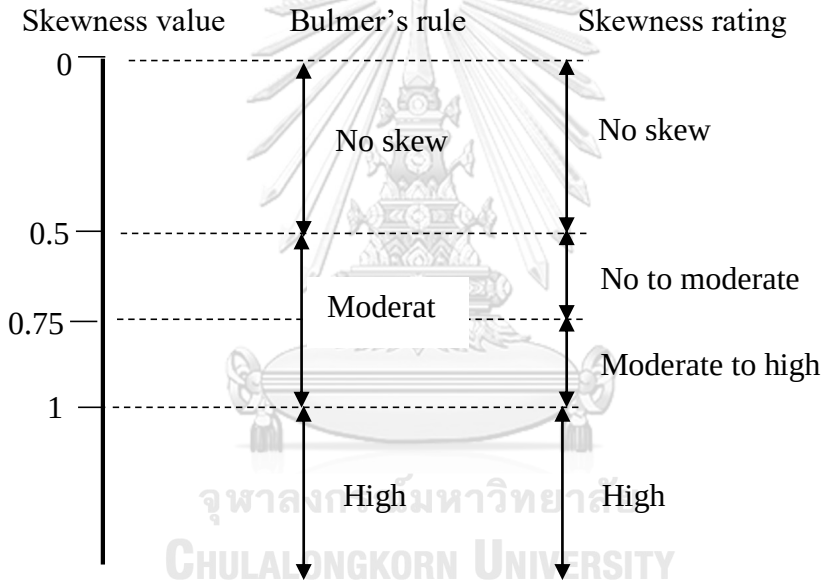


Figure 4.15 Comparison between Bulmer's rule of skewness and skewness rating

Because performance can skewed to either expected direction or the opposite, skeweness rating have both of positive and negative value depends on its direction. If performance is skewed to the expected direction, then skewness rating are positive value, otherwise skewness rating is negative value. Supposed that there is a supplier who has performance skewed to the disfavor direction, the MVS of this supplier would be negative value, since CV is positive. Therefore, total weight MVS of this supplier will be deducted by this negative weight MVS. By using this algorithm, it is able to

include skewness effect into the decision matrix. The skewness rating is presented in Table 4.12.

Table 4.12 Skewness rating

Skewness	Rating		Description
	Expected	Opposite	
No skew	1	-1	$-0.5 < Sk < 0.5$
No skew to moderate skew	2	-2	$-0.75 < Sk \le 0.5$ or $0.5 \le Sk < 0.75$
Moderate to high skew	3	-3	$-1 < Sk \le -0.75$ or $0.75 \le Sk < 1$
Highly skew	4	-4	$Sk \le -1$ or $Sk \ge 1$

In summary, selecting supplier using FMEA is the approach emphasizes on risk's perspective while SMSA takes tendency to perform better into account. With different perspective, the objective of the two methods are certainly different. FMEA seeks for suppliers who has lower risk of failure, while SMSA seeks for suppliers who has tendency to improve their performance. The differences between the two methods is summarized and presented in Figure 4.16.

	FMEA	SMSA
Approach	Measure failure mode	Measure success mode
Objective	Select supplier with lowest risk of failure	Select supplier with highest potential of success
Combinations	Determine combination: - Severity - Occurrence - Detectability ↓ Calculate RPN: RPN = $S \times O \times D$ ↓ Calculate Weight RPN: Weight RPN = Weight x RPN The lower weigh RPN means the better supplier.	Determine combination: - Mean - Standard deviation - Skewness ↓ Calculate MVS: MVS = $\frac{Mean}{SD} \times Sk\ rating$ ↓ Calculate Weight RPN: Weight RPN = Weight x RPN The greater weigh MVS means the better supplier.

Figure 4.16 Comparison between FMEA and SMSA method

4.5.2 Proposed SMSA Decision Matrix and Framework

As explanation of SMSA approach developed in this research, the decision matrix could be developed as shown in Table 4.13. Column 1 and column 2 in the matrix refer to main criteria and sub-criteria which are gathered from literature review. The third column is weight which denotes important weight of each criteria obtained from ANP approach. Column 4-6 refers to success assessment which represents supplier performance evaluation in 3 perspectives, i.e mean (M), standard deviation (SD), and skewness rating (SR). Company needs to evaluate these performance of all

alternative suppliers before implementing this matrix. Column 7 is MVS computating. Finally weight MVS of each criteria is calculated in column 8 in order to obtain total weight MVS.

Table 4.13 SMSA Decision matrix

Criteria	Sub-criteria	Weight (1)	Success Assessment			MVS (5) $=\frac{(2)}{(3)}\times(4)$	Weight MVS $=(1)\times(5)$
			M (2)	SD (3)	SR (4)		
Cost	Price						
	Other cost						
Delivery	Lead time						
	On-time delivery						
Quality	Product quality and reliability						
	Continuous improvement ability						
Supplier condition and relationship	Capacity and flexibility						
	Technical capability						
	Collaborative development						
Green supplier	Green manufacturing						
	Green product and design						
Supplier risk	Natural risk						
	Human risk						

To implement this decision matrix, this research proposes supplier selecting framework which has following steps:

1. Identify influential criteria: Actually this research already suggested influential criteria which should be considered for supplier selecting problem in Thai electronics industry, but in case that company has more additional criteria or company is in different industry, then the changing of criteria may occur. The list of criteria must be put in the first and second column of matrix.

2. Identify important weight: Compare importance of each criteria then put the important weight in the third column. Actually there are many methods to use in order to obtain important weight but this research suggests ANP approach as this method consider the dependency among criteria and able to deal with both of qualitative and quantitative criteria.

3. Evaluate supplier performance: Evaluate historical performance of all alternative suppliers into 3 characteristics, which are, mean (M), standard deviating (SD), and skewness. Then put the data of M and SD in column 4 and column 5, respectively.

4. Identify skewness rating: Set level of skewness rating then transform skewness value into skewness rating (SR) and put the value of skewness rating in column 6. If performance is skewed to the expected direction, then SR is positive. Otherwise, SR is negative. Here are the suggested skewness rating

- $-0.5 < Sk < 0.5$ SR = 1 or SR = -1
- $-0.75 < Sk \leq 0.5$ or $0.5 \leq Sk < 0.75$ SR = 2 or SR = -2
- $-1 < Sk \leq -0.75$ or $0.75 \leq Sk < 1$ SR = 3 or SR = -3
- $Sk \leq -1$ or $Sk \geq 1$ SR = 4 or SR = -4

5. Compute MVS: Calculate MVS by using the following equation then put MVS in column 7.

$$\frac{Mean}{SD} \times Sk \ rating$$

6. Calculate weight MVS: Calculate weight MVS which is the multiplication between weight (column 3) and MVS (column 7).

7. Select supplier: Supplier who has highest total weight MVS is supplier who has highest possibility to perform better than expected.

Table 4.14 shows the example of implementing decision matrix.

Table 4.14 Example of implementing decision matrix

Main criteria	Sub-criteria	Weight	Supplier A					Supplier B				
			Success Assessment			MVS	Weight MVS	Success Assessment			MVS	Weight MVS
			M	SD	SR			M	SD	SR		
Cost	Price	0.1153	8	0.8	1	20	2.31	8.5	0.667	1	12.75	1.47
	Other cost	0.0877	6	1.167	4	20.57	1.85	8	1.83	-2	-8.73	-0.77
Delivery	Lead time	0.0729	45	2.5	4	18	1.31	45	7.5	-4	-24	-1.75
	On-time delivery	0.0536	96	3	4	64	3.43	90	4.17	1	21.6	1.16
Green supplier	Green manufacturing	0.0978	60	1.667	4	36	3.52	50	1.83	1	27.27	2.67
	Green product and design	0.0864	70	5	4	28	2.42	70	1.167	1	60	5.18
Quality	Product quality and reliability	0.0526	4	0.833	4	19.2	1.01	4	1.67	1	2.4	0.13
	Continuous improvement ability	0.0718	80	3.333	4	-96	-6.89	78	3.333	-4	-93.6	-6.72
Supplier risk	Natural risk	0.086	99	4	3	24.75	2.13	70	7.33	1	9.55	0.82
	Human risk	0.0866	60	6.667	1	27	2.34	40	6.5	-3	-18.46	-1.6
Supplier's condition and relationship	Capacity and flexibility	0.0428	80	3.333	1	24	1.03	75	2.5	1	30	1.28
	Technical capability	0.0731	80	5	3	32	2.34	82	4.17	-2	-39.6	-2.89
	Collaborative development	0.0735	70	0.8	4	32.31	2.38	40	6.667	-3	-18	-1.32
						Total	19.12				Total	-2.34

From the decision matrix in Table 4.14, supplier A and B are evaluated. The result shows that total weight MVS of supplier A and B are 19.12 and -2.35, respectively. This indicates that, supplier A has higher possibility to be success or perform better than buyer's expected. In contrast, B has possibility to perform worse than A and also worse than buyer's expected as its weight MVS is negative. Therefore, in this case, the decision matrix suggests buyer to select supplier A rather than B.

4.5.2 Decision Matrix Validation

The verification of the proposed decision matrix is conducted by comparing the result between excluding and including skewness in the decision matrix. In questionnaire, the respondent is asking to evaluate performance of 2 suppliers. One is the most prefer supplier who is the first priority to be selected, and another one is less priority supplier. Performance of these two types of supplier as well as important weight of each company is used as the input data. The result of which supplier should be selected from each decision matrix is compared with the judgment of buyer's obtained from questionnaire. If the judgments are the same, then it is count as match result. The steps of verification is illustrated in Figure 4.17

Compare the matching between result of matrix and buyer's judgment, the assumption is the judgment of purchasing manager who has great experience in purchasing and dealing with suppliers is the right decision. Because it reflect the real decision of selecting supplier. Therefore, supplier who has the best performance must is the one who is selected.

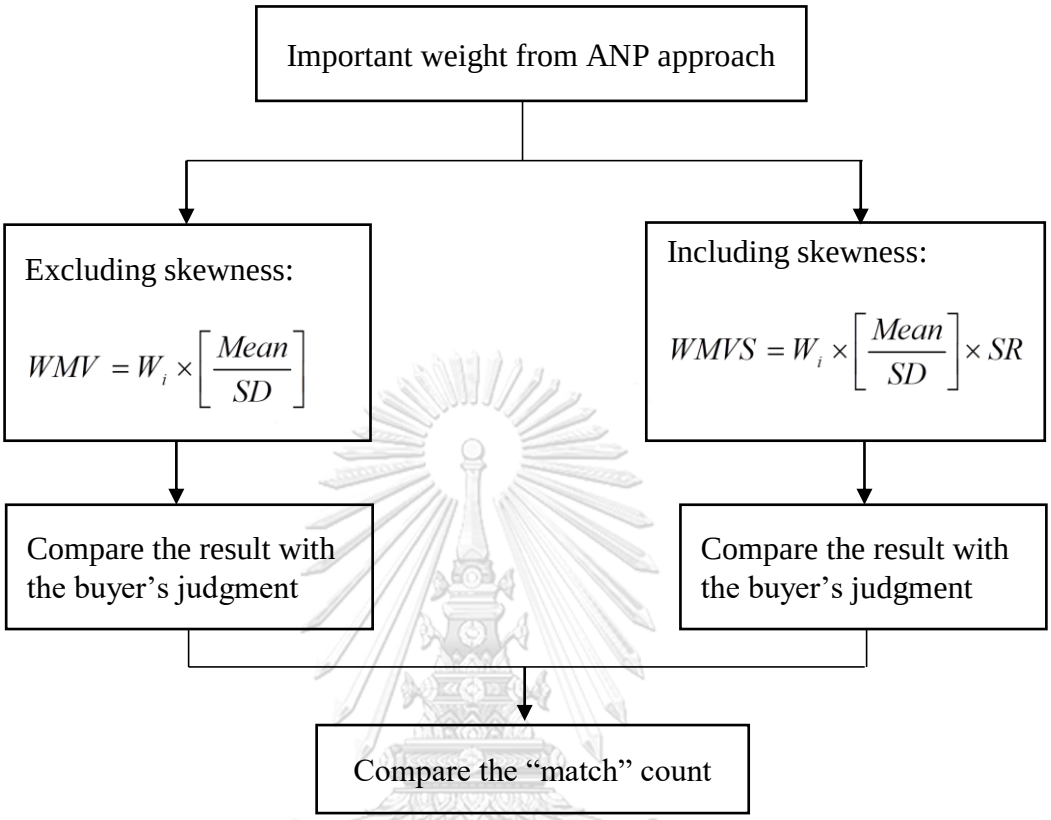


Figure 4.17 Validation of decision matrix

In Figure 4.17, using decision matrix which ignoring skewness, the overall %match is 75%, on the other hand there is 25% of mismatch result. Classified by size, the %match of medium-sized and large-sized manufacturing is about 78% and 71%, respectively. Large-sized manufacturers have larger gap of mismatch. Using the decision matrix which include skewness into consideration, all sample companies have the same judgment as buyer's selection.

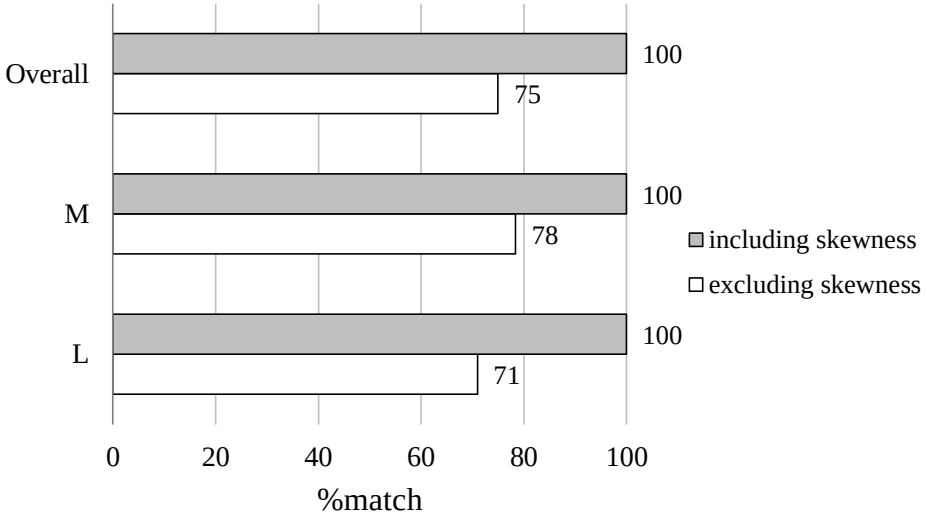


Figure 4.18 Comparison between FMEA and SMSA method

The mismatch result means buyer select supplier who has lower weight score of performance calculated from the decision matrix. The mismatch shows that the judgment by decision matrix is different from actual judgment. Of course buyer prefers supplier whose performance is better. In other words, the judgment from buyer is the right judgment but the question is why the result from one decision matrix is same as buyer's judgment while another one is in contrast. The difference between these two decision matrixes is skewness. Hence, skewness should not be ignored when evaluating performance. In other words, the develop decision matrix is the practical way used to select the most suitable supplier.

In summary this chapter analyzes the data from survey, in order to obtain important weight of each criteria and prove that skewness effect does exist. Moreover, the result shows that in some criteria, using mean and SD cannot distinguish between first priority and less priority suppliers. In other words, skewness is the best index to distinguish between favorable and unfavorable suppliers which buyers should not neglect when evaluating suppliers. Finally, the SMSA approach which is the decision matrix including skewness is developed in order to select supliers.

CHAPTER 5
CONCLUSION

This chapter concludes this research as well as its implication and recommendation for future study.

5.1 Conclusion and Discussion

. Among several activities in logistics management, this research concentrating on supplier selection problem which is one of important decision to be made in purchasing and procurement activity. This research has 2 objectives. One is to identify influential criteria and their important weight of supplier selection problem for Thai electronics industry. Another objective is to develop decision matrices for selecting supplier based on mean-variance-skewness.

To conduct this research, the initial set of criteria are gathered from literature review and confirmed by experts in purchasing. Totally, there are 6 main criteria with 13 sub-criteria. With many criteria involved in making a decision to select the most appropriate supplier, this research identified important weight of each criteria by using ANP approach. Also this research introduced the important role of skewness. In supplier selection problem, normally buying firms choose supplier which has best performance. But supplier with greatest expected performance or highest average performance does not mean the most suitable one. That is to say that, actually performance should be measured into 3 perspectives, mean, variance and skewness (M-V-S) combined together.

From literature review, it is found that the maximum sample size from previous study in similar topic is 60 respondents. Therefore, this research set minimum sample size required equals to 60 sample sizes. The data was collected by 2 ways, face-to-face interview and questionnaire. The result from both ways are not significantly different. However, it is found that collecting data by using questionnaire required more time, especially the part of comparison among criteria. Because when it was found that inconsistency existed, the questionnaire was sent back to respondent to re-judge.

Totally 77 sample sizes were collected. 53 samples are from interview whereas 24 samples are from questionnaire.

From result conclusion in Table 5.1, lead time is the highest influential factor on supplier selection, follows by price, continuous improvement ability, capacity and flexibility and product quality, and reliability, respectively. The results indicate the nature of nowadays business environment which is more time sensitive and higher responsive.

Table 5.1 Result conclusions

Rank	Weigh	Sub-criteria	Effect of Performance perspective					
			M-sized buyers			L-sized buyers		
			Mean	SD	Sk	Mean	SD	Sk
1	0.0910	Lead time	✓	✓	✓	✓	✓	✓
2	0.0869	Price	×	✓	×	✓	✓	×
3	0.0806	Continuous improvement ability	×	×	✓	✓	×	✓
4	0.0791	Capacity and flexibility	✓	×	✓	✓	×	✓
5	0.0786	Product quality and reliability	✓	✓	✓	✓	✓	✓
6	0.0766	Technical capability	×	✓	✓	×	✓	✓
7	0.0755	Natural risk	✓	✓	✓	✓	✓	✓
8	0.0751	Other cost	✓	✓	✓	✓	×	✓
9	0.0750	On-time delivery	✓	✓	✓	✓	×	✓
10	0.0736	Human risk	✓	✓	✓	×	✓	✓
11	0.0711	Green manufacturing	×	×	✓	×	✓	✓
12	0.0690	Green product and design	×	×	✓	×	✓	✓
13	0.0678	Collaborative development	✓	✓	✓	✓	×	✓

In order to develop decision matrix, the existence of skewness effect is proved prior to developing decision matrix. The data of performance evaluation between first priority supplier and less priority was collected and analyzed. Performance are measured in 3 characteristics, which are, mean, SD, and skewness as shown in Table 5.1. The result surprisingly shows that, in some criteria, there is no difference on mean and SD between first priority and less priority suppliers. Only skewness does. For

example, green manufacturing, and green product and design. Also, skewness is the best index to distinguish between first priority and less priority suppliers, while mean is the worst index. This result indicates that when evaluating supplier, consideration only on mean and SD is not enough, but skewness should also be considered.

The result analysis proved that skewness of performance between first priority and less priority suppliers are skewed to different direction. While performance of good suppliers are skewed to the expected direction, for example, lead time is right-skewed, performance of bad suppliers are skewed to opposite direction. This indicates that good suppliers should have tendency to perform better than buyers' expectation. In contrast, bad suppliers perform worse than expectation or promised performance.

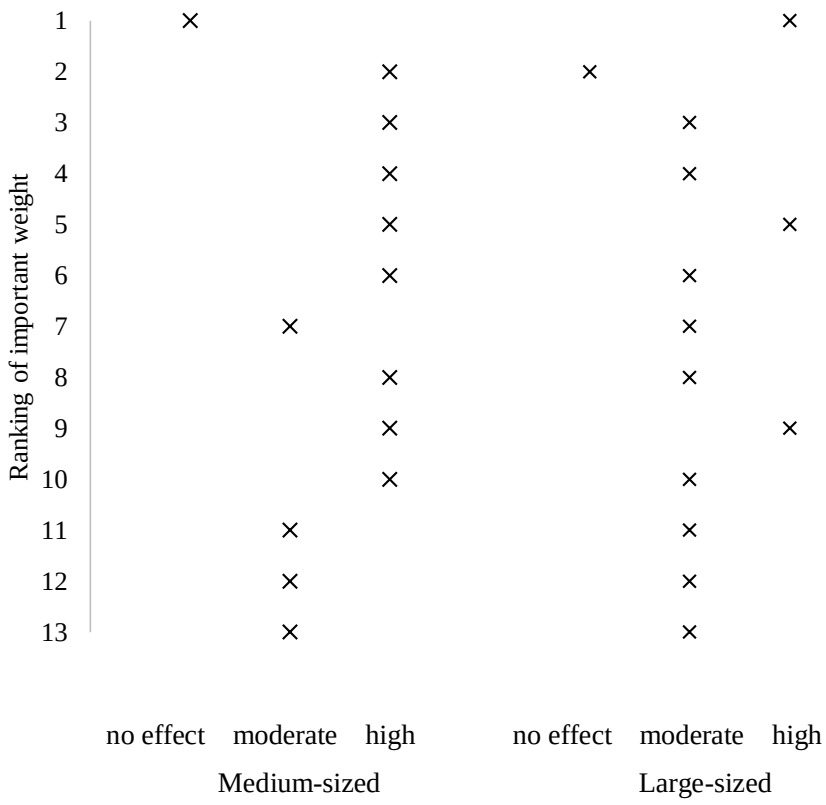


Figure 5.1 Relationship between important weight ranking and skewness effect

From Figure 5.1, the vertical axis is the ranking of important weight based on important weight in descending order. It shows that skewness effect has no relationship between rankings. Criteria with high or low important weight are all having skewness

effect. Some have moderated effect while some have highly effect. But there is no significant relationship between ranking and skewness effect. However, skewness plays more important role on suppliers' performance of medium-sized manufacturers than large-sized manufacturers.

Finally, this research develop decision matrix to for selecting proper supplier. By adapting concept of FMEA (Failure Mode and Effects Analysis) which measure risk or failure mode by determining severity, occurrence and detection of failure then transform to RPN score. Greater RPN denotes higher chance of failure or lower satisfaction. But instead of evaluate failure mode, this research evaluate supplier performance based on success mode which is called Success Mode with Skewness Analysis (SMSA) by considering performance efficiency, performance stability, and performance tendency which is measured by mean, standard deviation, and skewness respectively. Table 5.2 presents decision matrix proposed by this research.

Table 5.2 Decision matrix of SMSA approach

Criteria	Sub-criteria	Weight	Success Assessment			MVS (5)	Weight MVS
			M	SD	SR		
		(1)	(2)	(3)	(4)	$=\frac{(2)}{(3)}\times(4)$	$=(1)\times(5)$
Cost	Price						
	Other cost						
Delivery	Lead time						
	On-time delivery						
Quality	Product quality and reliability						
	Continuous improvement ability						
Supplier condition and relationship	Capacity and flexibility						
	Technical capability						
	Collaborative development						
Green supplier	Green manufacturing						
	Green product and design						
Supplier risk	Natural risk						
	Human risk						

The comparison of judgment between including and excluding skewness in consideration with the actual judgment of buyers were analyzed. The result shows that selecting supplier including skewness into consideration i more valid. Hence, skewness should not be ignored when evaluating performance. In other words, the develop decision matrix is the practical way used to select the most suitable supplier. Figure 5.2 shows the decision framework for supplier selection suggested by this research.

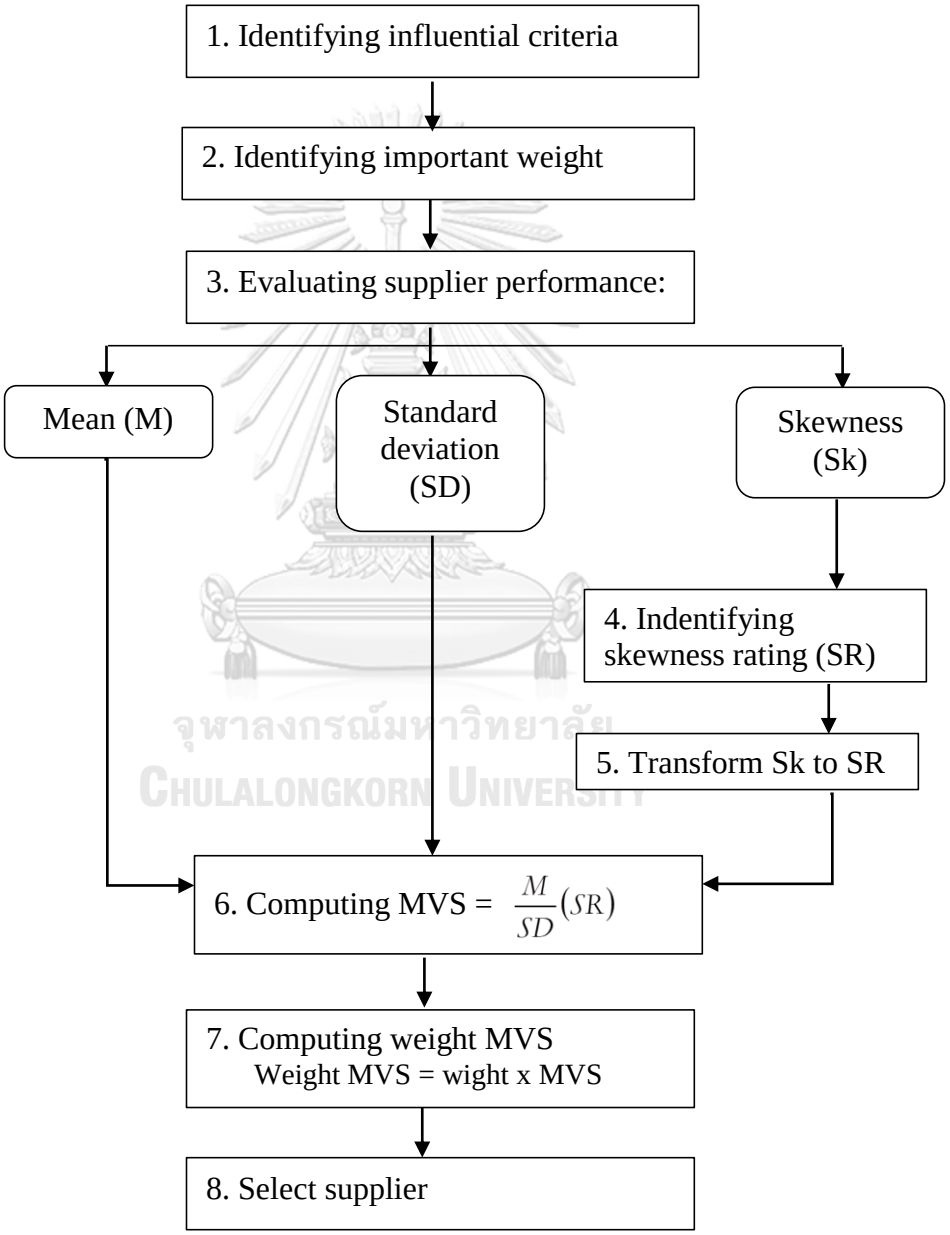


Figure 5. 2 Supplier selection framework of SMSA approach

Compare to previous literature in supplier selection problem, the criteria set used in this research is similar to previous study. Since it is first extracted from Disckson's research in 1966 then selected most widely used criteria from review. But since this research focuses on uncertainty or criteria which could have performance fluctuated all the time, therefore only dynamic criteria are considered in this research. In other words, to clearly explore skewness effect, this research disregards static criteria. It is interesting for future research to combine both of static and dynamic criteria together.

Also, when evaluating supplier performance, previous literatures always considered on suppliers which have high expected average performance and low variance but neglect uncertainty or the possibility that suppliers would performance different from expected performance. Although there is a research studied by P-S. Chen and Wu in 2013, which suggested to consider this uncertainty when evaluating supplier performance. In the research by P-S. Chen and Wu, they defined the uncertainty by emphasizing on the possibility of supplier to perform worse than expected or the possibility to be failure by applying FMEA concept. But this research is focusing on different aspect since it emphasizes on the possibility of supplier to perform better than expected or the possibility to be success.

Moreover, this research not only suggest to combine all 3 performance characteristics together when evaluating supplier performance, but it also compare the effect of each characteristic or the ability to distinguish between first priority and less priority suppliers. The surprising result is that skewness is the best index to distinguish between first priority and less priority suppliers, while mean is the worst index

5.2 Implication

Findings and implications from this study has two-folds. The following parts are discussed about implications from this research in term academic contributions and business managerial implications.

5.2.1 Academic contribution

The most important academic contribution from this research is the discovering and determining important role of skewness in supplier selection problem. In circumstance which is full of uncertainties, supplier's performance is unstable and fluctuated throughout the period of time. In order to evaluating, nor only supplier selection problem but also other decision problems in logistics field, researchers always consider about mean and SD but ignoring skewness. From the result, it is found that skewness really plays important role on supplier performance and it is the better index which able to distinguish between favorable and unfavorable supplier than considering only mean and SD as shown in Table 5.1. Hence, when evaluate performance, the decision maker should consider performance skewness on top of the average and variance (or standard deviation). This study is the empirical study of performance evaluating of Thai electronics industry where 3 performance perspectives, average efficiency, performance stability and performance tendency, are included in this study

Another contribution is the development of SMSA decision matrix which consists of three performance perspectives measure by mean, standard deviation, and skewness, and combines them together to propose new method to evaluate performance. But instead of evaluating alternatives based on its failure mode like FMEA concept, this research adapted to evaluate suppliers' performance based on their success mode.

5.2.2 Business managerial Implication

The managerial implication in this research has 2 major practical implication. One is for buyer firms, and another one is for supplier firms.

- For buyers, it is obvious that skewness has strongly impact on suppliers' performances for both of good and bad suppliers. Therefore, to evaluate and compare among potential suppliers, not only average performance or variance should be brought into consideration, but buyers should also consider skewness by analyzing historical performance of potential suppliers. To combine these 3 characteristics, the concept of M-V-S evaluating can be implemented. This research proposed the decision matrix to

compare supplier performance. Therefore, buyers' firm can implement the proposed decision matrix in order to select supplier.

- For supplier's side, this research provide the guidance of which performance perspective should be improved for each criteria in order to become buyer's first priority supplier to be selected. From the conclusion shown in Table 5.1, judging by buyer's point of view, it shows that there is no difference between first priority and less priority supplier in the perspective of mean and SD in some criteria. For example, criteria of lead time of medium-sized manufactures, all 3 perspectives have difference between first priority and less priority suppliers. Therefore, if less priority suppliers, want to improve themselves to become first priority supplier, they should improve their performance for all 3 characteristics. But for criteria of continuous improvement ability, only skewness is different between less priority and first priority suppliers. This implies that, if less priority suppliers want to improve themselves to become first priority supplier, they should focus on improving their skewness or the ability to provide better performance than buyers' expectation rather than improving average performance or performance stability. Because skewness is only one index which can be used to distinguish between first priority and less priority suppliers.

5.3 Limitations

1. Data variation: This research studied about supplier selection problem of Thai electronics industry which set home electrical machine as target group. However, due to the vast number of manufacturers in this cluster as well as several manufacturer types existed, there is still variation within sample size. Although this research tried to minimize the variation by grouping samples based on their company size, there are other source of variation, for example, types of manufacturer. But in practically, companies do not produce exactly same product as their declaration based on TSIC (Thailand Standard Industrial Classification) number of Department of Industrial Works, Ministry of industry. Some companies produce not only product they registered on TSIC type but other products as well. These products are mixed between similar products to their product line or entirely different products. While some companies have completely changed their product line from their TSIC types but did not change their TSIC number. Also, some large-sized company which have many manufacturing plants,

each plant produces different product but they only registered their key product in TSIC. Therefore, in this study only size of company are analyzed. The future research should cover with this limitation.

2. Data collecting: In this research data collecting is conducted by 2 ways, i.e., interview and questionnaire. Although there is no different between the data obtained from both ways but it is found that collecting data by using questionnaire is likely to have more mistake and take longer time to correct. Especially in questionnaire section 1 which asking respondent to compare criteria based. In AHP approach, after getting the comparisons, the results will be check if there is any inconsistency. For interviewing, the inconsistency ratio can be calculated along with interviewing. . So if there is any inconsistency, respondent will be asked to re-judgment the comparison instantly. But using questionnaire, if the result is found that inconsistency existed in the comparison, questionnaire will be sent back to respondent to re-judge. Then the result will be analyzed again.

3. Bias in evaluating performance: Another issue is, there could be bias when respondent evaluate performance of suppliers in some criteria. Especially if the time period that supplier and buyer have been doing business together. With longer time, buyers would have seen the changing or improvement on suppliers continuously. Therefore, it has a chance that buyer will give higher satisfaction score to this supplier. In the opposite, if supplier and buyer has been started doing business together for short period, then it has a chance that buyer will give lower score to this supplier because the improvement has not obviously occurred.

5.4 Future Research

One interesting issue that future research should consider is classification of suppliers. In this research classifies customer into 2 types, 1) first priority supplier who is the first option for buyer to buy product from, and 2) less priority supplier who has least favorable and would be the last option for buyer to buy product from. The result shows that, for less priority suppliers, number of criteria with no skewness effects of large-sized manufacturers is greater than medium-sized manufacturers. This indicates that, for buyers with large size, they have power over their suppliers. Therefore, they

can force their suppliers to maintain their performance. Even suppliers cannot improve themselves or have better performance than buyers' expectation, but they must keep their level of efficiency not to be lower than customers' expectation. This implies that, actually suppliers have 3 types, 1) first priority suppliers who have performance skewed to the expected direction or tend to perform better than expected, 2) moderate priority suppliers who have no skewness effect or who perform exactly as expected, and 3) less priority suppliers who have performance skewed to the opposite direction or perform worse than expected. Future research should also consider suppliers who have performance in between of first priority and less priority suppliers.

Moreover, comparison between 2 suppliers essentially judged by skewness may not be able to apply in any case. Supposed that there are 2 alternative suppliers. One provides very short lead time at 10 days but high instability and inappropriate skewness. Another one provides longer lead time at 45 days with very low SD, high stability and appropriate skewness. Of course buyers prefer suppliers who would perform better than their expectation with high stability because it is easier for buyers to make plan and operate. But since these 2 suppliers have much different average performance, it might be worth to select supplier who perform worse than expected. Because even this supplier would provide longer lead time than promised lead time but it is still very shorter than the one who perform better than expected. Therefore, there might be the cut-off point (critical point) that separate 2 decisions. Future research should take this issue into consideration.

From findings in this study, skewness is an index that could be used to represent the tendency of improvement. With high skewness, suppliers seem to have higher performance than buyers' expectation and tend to be able to improve their performance. In addition, by improving on skewness, sooner or later, skewed performance seems to gradually shift to the expected direction and be able to transform to normal distribution. Future researchers should also study if improving skewness seems to be continuously improved firm's performance like PDCA concept.

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APPENDIX

APPENDEX A

แบบสอบถามเพื่อการวิจัย

ด้วยข้าพเจ้า นางสาวอรณิชา อนุชิตชาญชัย นิสิตปริญญาเอก สาขาวิชาการจัดการด้านโลจิสติกส์ จุฬาลงกรณ์มหาวิทยาลัย กำลังดำเนินการวิจัยเรื่อง **การคัดเลือกผู้ส่งมอบแบบหลายเกณฑ์เชื่อมโยงโดยการประเมินความไม่แน่นอนของประสิทธิภาพ (Multi-dependent Criteria Supplier Selection with Uncertain Performance Evaluation)** โดยมีวัตถุประสงค์ของงานวิจัยคือ

1. เพื่อศึกษาถึงปัจจัยที่มีผลในการคัดเลือกผู้ส่งมอบ (Supplier) วัตถุดิบในการผลิตสำหรับอุตสาหกรรมไฟฟ้าและอิเล็กทรอนิกส์ในประเทศไทย
2. เพื่อพัฒนาวิธีการในการตัดสินเลือกผู้ส่งมอบที่มีประสิทธิภาพและแม่นยำมากขึ้น โดยพิจารณาถึงความไม่แน่นอนของประสิทธิภาพของผู้ส่งมอบ

เพื่อให้บรรลุวัตถุประสงค์งานวิจัยดังกล่าวข้างต้น ผู้วิจัยต้องกำหนดปัจจัยที่มีผลในการคัดเลือกผู้ส่งมอบสำหรับอุตสาหกรรมไฟฟ้าและอิเล็กทรอนิกส์ในประเทศไทย เพื่อนำไปสร้างแบบสอบถามที่ใช้ในการศึกษาถึงน้ำหนักความสำคัญของแต่ละปัจจัยและพัฒนาวิธีการคัดเลือกผู้ส่งมอบต่อไป

ข้อมูลจากท่านจะเป็นประโยชน์อย่างยิ่งสำหรับงานวิจัยนี้ ดังนั้น ผู้วิจัยจึงใคร่ขอความอนุเคราะห์จากท่านในการตอบแบบสอบถามนี้ รวมถึงอาจมีการสัมภาษณ์เพิ่มเติมเพื่อให้งานวิจัยนี้ประสบความสำเร็จลุล่วง ทั้งนี้ ข้อมูลต่าง ๆ จะถูกเก็บเป็นความลับ ไม่มีการเผยแพร่ และไม่มีการเปิดเผยข้อมูลเป็นรายบุคคล ตามหลักจริยธรรมและจรรยาบรรณทางวิชาการ ทางผู้วิจัยขอขอบพระคุณท่านและองค์กรของท่านเป็นอย่างสูง ที่ได้สละเวลาในการตอบแบบสอบถามนี้หรือการให้สัมภาษณ์ใด ๆ เพิ่มเติม

ขอแสดงความนับถือ

อรณิชา อนุชิตชาญชัย

ส่วนที่ 1 ข้อมูลเบื้องต้นของผู้ตอบแบบสอบถาม

วันที่ตอบแบบสอบถาม: _____

ชื่อ: _____ นามสกุล: _____ ตำแหน่ง: _____

บริษัท/หน่วยงาน: _____ ประสบการณ์ทำงาน: _____

เบอร์ติดต่อ: _____ อีเมลล์: _____

ส่วนที่ 2 ปัจจัยที่มีผลในการคัดเลือกผู้ส่งมอบเบื้องต้น

จากปัจจัยที่มีผลในการคัดเลือกผู้ส่งมอบเบื้องต้นที่ทางผู้วิจัยได้คัดเลือกมา ท่านคิดว่าปัจจัยเหล่านี้มีผลต่อการตัดสินใจคัดเลือกผู้ส่งมอบสำหรับอุตสาหกรรมไฟฟ้าและอิเล็กทรอนิกส์ในประเทศไทยหรือไม่

ปัจจัยหลัก	ปัจจัยรอง	ความหมาย	ผลการพิจารณา	
			มีผล	ไม่มี
ตัวอย่าง				
ปัจจัย ก			✓	
ปัจจัย ข				✓
ปัจจัยที่มีผลในการคัดเลือกผู้ส่งมอบเบื้องต้นที่ทางผู้วิจัยได้คัดเลือก				
(1) ต้นทุน (Cost)	(1.1) ราคา (Price)	ราคารวมที่ผู้ส่งมอบเสนอกับผู้ซื้อ		
	(1.2) ต้นทุนอื่น ๆ (Other cost)	ค่าใช้จ่ายอื่น ๆ นอกเหนือจากราคาวัตถุดิบที่ต้องจ่ายในการสั่งซื้อ เช่น ค่าขนส่ง ค่าดำเนินการ		
(2) คุณภาพ (Quality)	(2.1) คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ (Product quality and reliability)	คุณภาพของผลิตภัณฑ์ที่เป็นไปตามที่ผู้ซื้อต้องการ ประเมินได้ด้วยอัตราการตีกลับสินค้า (Return rate)		
	(2.2) ความสามารถในการปรับปรุงอย่างต่อเนื่อง (Continuous improvement ability)	แนวโน้มหรือความพยายามของผู้ส่งมอบที่จะพัฒนาผลิตภัณฑ์ให้มีคุณภาพสูงขึ้นเรื่อย ๆ		
(3) ความสามารถในการส่งมอบ (Delivery)	(3.1) ระยะเวลานำในการสั่งซื้อ (Lead time)	ช่วงเวลานำตั้งแต่เริ่มสั่งวัตถุดิบจนกระทั่งได้รับสินค้า		
	(3.2) อัตราการส่งมอบตรงเวลา (On-time delivery)	ความสามารถในการส่งมอบวัตถุดิบได้ครบถ้วนตรงตามเวลา ตามปริมาณที่สั่ง		
(4) ปัจจัยแวดล้อมของผู้ผู้ส่งมอบและความสัมพันธ์ (Supplier's condition and relationship)	(4.1) กำลังการผลิตและความยืดหยุ่น (Capacity and flexibility)	ความสามารถในการรองรับปริมาณการสั่งซื้อจากผู้ซื้อ และความรวดเร็วในการตอบสนองต่อการเปลี่ยนแปลง เช่น สเปคของผลิตภัณฑ์ ปริมาณ หรือกระบวนการ		
	(4.2) ความสามารถทางด้านเทคนิค (Technical capability)	ศักยภาพในการพัฒนาเทคโนโลยีให้ทันสมัย ทั้งการออกแบบผลิตภัณฑ์ และกระบวนการผลิต		
	(4.3) ความร่วมมือในการพัฒนา (Collaborative development)	ความร่วมมือและความช่วยเหลือจากผู้ส่งมอบในการพัฒนาความสามารถและประสิทธิภาพของพัฒนาผลิตภัณฑ์และกระบวนการผลิต		
(5) ผู้ส่งมอบสีเขียว (Green supplier)	(5.1) การผลิตสีเขียว (Green manufacturing)	ความใส่ใจต่อสิ่งแวดล้อมและกระบวนการผลิตของผู้ส่งมอบที่สามารถลดผลกระทบต่อสิ่งแวดล้อมลงได้		

ปัจจัยหลัก	ปัจจัยรอง	ความหมาย	ผลการพิจารณา	
			มีผล	ไม่มี
	(5.2) ผลิตภัณฑ์และการออกแบบสีเขียว (Green product and design)	การออกแบบผลิตภัณฑ์และบรรจุภัณฑ์ที่คำนึงถึงผลกระทบต่อสิ่งแวดล้อม เช่น เป็นผลิตภัณฑ์ที่ออกแบบนำกลับมาใช้ใหม่ได้ (Design for Recycle) หรือถอดประกอบได้ง่าย (Design for Disassembly)		
(6) ความเสี่ยง (Supplier risk)	(6.1) ความเสี่ยงจากธรรมชาติ (Natural risk)	โอกาสที่ประสิทธิภาพของผู้ส่งมอบจะไม่เป็นไปตามที่คาด อันเนื่องมาจากภัยธรรมชาติ และปัจจัยภายนอกที่ควบคุมไม่ได้		
	(6.2) ความเสี่ยงจากความผิดพลาดของบุคคล (Human risk)	โอกาสที่ประสิทธิภาพของผู้ส่งมอบจะไม่เป็นไปตามที่คาดอันเนื่องมาจากความผิดพลาดของพนักงานของผู้ส่งมอบ		

ส่วนที่ 3 ปัจจัยเพิ่มเติมและข้อเสนอแนะอื่น ๆ

นอกเหนือจากปัจจัยที่มีผลในการคัดเลือกผู้ส่งมอบเบื้องต้นที่ทางผู้วิจัยได้คัดเลือกมาในส่วนที่ 2 ท่านคิดว่าปัจจัยต่อไปนี้มีผลต่อการตัดสินใจคัดเลือกผู้ส่งมอบสำหรับอุตสาหกรรมไฟฟ้าและอิเล็กทรอนิกส์ในประเทศไทยหรือไม่

ปัจจัย	ความหมาย	ผลการพิจารณา	
		มีผล	ไม่มี
ความสามารถในอดีต (Performance history)	ความสามารถหรือผลงานในอดีตของผู้ส่งมอบ		
ทัศนคติ (Attitude)	ทัศนคติของผู้ส่งมอบ หรือแนวคิดในการทำงานของผู้ส่งมอบ		
ระบบการฝึกอบรม (Training Aids)	ระบบการพัฒนาบุคคลากรของผู้ส่งมอบ รวมถึงการช่วยเหลือในการฝึกอบรมพนักงานของผู้ซื้อในกรณีที่จำเป็น		
การควบคุมการดำเนินงาน (Operating controls)	ความสามารถในการควบคุมการปฏิบัติงานหรือกระบวนการ โดยเน้นที่ผู้บริหารระดับล่าง เช่น มีกระบวนการในการควบคุมการปฏิบัติงานของพนักงาน มีกระบวนการในการควบคุมความสามารถของกระบวนการในการผลิต (Process Capability) เป็นต้น		
ความสามารถในการบรรจุภัณฑ์ (Packaging ability)	ความสามารถของผู้ส่งมอบในการพัฒนาประสิทธิภาพของบรรจุภัณฑ์		
ความสามารถในการให้การบริการ (Repair service)	ความสามารถในการตอบสนองของผู้ส่งมอบในกรณีที่เกิดปัญหาต่าง ๆ ขึ้น		
ความประทับใจ (Impression)	ความประทับใจที่ผู้ซื้อมีต่อผู้ส่งมอบ		

ปัจจัย	ความหมาย	ผลการพิจารณา	
		มีผล	ไม่มี
ความสัมพันธ์ระหว่างพนักงานขององค์กรของผู้ซื้อและผู้ส่งมอบ (Labor relations record)	ความสัมพันธ์ระหว่างพนักงานขององค์กรผู้ซื้อและผู้ขาย		
ปริมาณที่เคยซื้อขายกันในอดีต (Amount of past business)	ปริมาณการสั่งซื้อที่ผ่านมาในอดีต หมายถึง ผู้ส่งมอบที่ผู้ซื้อเคยสั่งวัตถุดิบในปริมาณมากกว่ามีแนวโน้มจะได้รับคัดเลือก		
ข้อตกลงต่างตอบแทน (Reciprocal arrangements)	แนวโน้มที่ผู้ส่งมอบจะทำการซื้อสินค้าจากผู้ขายในอนาคต		
ความกระตือรือร้นของผู้ส่งมอบ (Desire for business)	ความกระตือรือร้น ความเอาใจใส่ และความเต็มใจช่วยเหลือผู้ซื้อจากผู้ส่งมอบ		
ความสามารถในการให้การบริการ (Service ability)	การให้บริการหรือคำแนะนำจากผู้ส่งมอบ รวมถึงความสามารถในการตอบสนองของผู้ส่งมอบในกรณีทีเกิดปัญหาต่าง ๆ ขึ้น		

ข้อเสนอแนะอื่น ๆ

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APPENDIX B

แบบสอบถามเพื่อการวิจัย

ด้วยข้าพเจ้า นางสาวอรณิชา อนุชิตชาญชัย นิสิตปริญญาเอก สาขาวิชาการจัดการด้านโลจิสติกส์ จุฬาลงกรณ์มหาวิทยาลัย กำลังดำเนินการวิจัยเรื่อง **การคัดเลือกผู้ส่งมอบแบบหลายเกณฑ์เชื่อมโยงโดยการประเมินความไม่แน่นอนของประสิทธิภาพ (Multi-dependent Criteria Supplier Selection with Uncertain Performance Evaluation)** โดยมีวัตถุประสงค์ของงานวิจัยคือ

1. เพื่อศึกษาถึงปัจจัยที่มีผลในการคัดเลือกผู้ส่งมอบ (Supplier) วัตถุดิบในการผลิตสำหรับอุตสาหกรรมไฟฟ้าและอิเล็กทรอนิกส์ในประเทศไทย
2. เพื่อพัฒนาวิธีการในการตัดสินเลือกผู้ส่งมอบที่มีประสิทธิภาพและแม่นยำมากขึ้น โดยพิจารณาถึงความไม่แน่นอนของประสิทธิภาพของผู้ส่งมอบ

เพื่อให้บรรลุวัตถุประสงค์งานวิจัยดังกล่าวข้างต้น ทางผู้วิจัยต้องการทราบน้ำหนักความสำคัญของปัจจัยทั้งหลาย โดยแบบสอบถามชุดนี้ประกอบไปด้วย 3 ส่วน ได้แก่

- ส่วนที่ 1 การสอบถามข้อมูลเบื้องต้นของผู้ตอบแบบสอบถาม
- ส่วนที่ 2 การเปรียบเทียบน้ำหนักความสำคัญของแต่ละปัจจัย โดยประยุกต์ใช้เทคนิคกระบวนการโครงข่ายเชิงวิเคราะห์ (Analytic Network Process) ซึ่งต้องใช้การเปรียบเทียบแบบคู่ โดยรายละเอียดและขั้นตอนการตอบแบบสอบถามจะได้นำเสนอถัดไป
- ส่วนที่ 3 การประเมินประสิทธิภาพของผู้ส่งมอบในด้านต่าง ๆ โดยคำนึงถึงความไม่แน่นอนของประสิทธิภาพ โดยผู้ประเมินจะเลือกผู้ส่งมอบในปัจจุบัน หรือผู้ที่เข้าข่ายได้รับเลือกเป็นผู้ส่งมอบที่ขายวัตถุดิบเหมือนกัน 2 ราย และทำการประเมินประสิทธิภาพของผู้ส่งมอบ

ข้อมูลจากท่านจะเป็นประโยชน์อย่างยิ่งสำหรับงานวิจัยนี้ ดังนั้น ผู้วิจัยจึงใคร่ขอความอนุเคราะห์จากท่านในการตอบแบบสอบถาม รวมถึงอาจมีการสัมภาษณ์เพิ่มเติมเพื่อให้งานวิจัยนี้ประสบความสำเร็จลุล่วง ทั้งนี้ ข้อมูลต่าง ๆ จะถูกเก็บเป็นความลับไม่มีการเผยแพร่ และไม่มีการเปิดเผยข้อมูลเป็นรายบุคคล ตามหลักจริยธรรมและจรรยาบรรณทางวิชาการ ทางผู้วิจัยขอขอบพระคุณท่านและองค์กรของท่านเป็นอย่างสูง ที่ได้สละเวลาในการตอบแบบสอบถามนี้หรือการให้สัมภาษณ์ใด ๆ เพิ่มเติม

ขอแสดงความนับถือ
อรณิชา อนุชิตชาญชัย

ตารางที่ 1 ปัจจัยหลัก/ปัจจัยรองที่มีผลต่อการตัดสินใจคัดเลือกผู้ส่งมอบ และความหมาย

ปัจจัยหลัก	ปัจจัยรอง	ความหมาย
(1) ต้นทุน (Cost)	(1.1) ราคา (Price)	ราคาจริงของวัตถุดิบที่ผู้ส่งมอบเสนอกับผู้ซื้อ
	(1.2) ต้นทุนอื่น ๆ (Other cost)	ค่าใช้จ่ายอื่น ๆ นอกเหนือจากราคาวัตถุดิบที่ต้องจ่ายในการสั่งซื้อ เช่น ค่าขนส่ง ค่าดำเนินการ เป็นต้น
(2) คุณภาพ (Quality)	(2.1) คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ (Product quality and reliability)	คุณภาพของผลิตภัณฑ์ที่เป็นไปตามที่ผู้ซื้อต้องการ ประเมินได้ด้วยอัตราการตีกลับสินค้า (Return rate)
	(2.2) ความสามารถในการปรับปรุงอย่างต่อเนื่อง (Continuous improvement ability)	แนวโน้มหรือความพยายามของผู้ส่งมอบที่จะพัฒนาผลิตภัณฑ์ให้มีคุณภาพสูงขึ้นเรื่อย ๆ
(3) ความสามารถในการส่งมอบ (Delivery)	(3.1) ระยะเวลานำในการสั่งซื้อ (Lead time)	ช่วงเวลานำตั้งแต่เริ่มสั่งวัตถุดิบจนกระทั่งได้รับสินค้า
	(3.2) อัตราการส่งมอบตรงเวลา (On-time delivery)	ความสามารถในการส่งมอบวัตถุดิบได้ครบถ้วนตรงตามเวลา ตามปริมาณที่สั่ง
(4) ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์ (Supplier's condition and relationship)	(4.1) กำลังการผลิตและความยืดหยุ่น (Capacity and flexibility)	ความสามารถในการรองรับปริมาณการสั่งซื้อจากผู้ซื้อและความรวดเร็วในการตอบสนองต่อการเปลี่ยนแปลง เช่น สเปคของผลิตภัณฑ์ ปริมาณ หรือกระบวนการ
	(4.2) ความสามารถทางด้านเทคนิค (Technical capability)	ศักยภาพในการพัฒนาเทคโนโลยีให้ทันสมัย ทั้งการออกแบบผลิตภัณฑ์ และกระบวนการผลิต
	(4.3) ความร่วมมือในการพัฒนา (Collaborative development)	ความร่วมมือและความช่วยเหลือจากผู้ส่งมอบในการพัฒนาความสามารถและประสิทธิภาพของพัฒนาผลิตภัณฑ์และกระบวนการผลิต
(5) ผู้ส่งมอบสีเขียว (Green supplier)	(5.1) การผลิตสีเขียว (Green manufacturing)	ความใส่ใจต่อสิ่งแวดล้อมและกระบวนการผลิตของผู้ส่งมอบที่สามารถลดผลกระทบต่อสิ่งแวดล้อมลงได้
	(5.2) ผลิตภัณฑ์และการออกแบบสีเขียว (Green product and design)	การออกแบบผลิตภัณฑ์และบรรจุภัณฑ์ที่คำนึงถึงผลกระทบต่อสิ่งแวดล้อม เช่น เป็นผลิตภัณฑ์ที่ออกแบบนำกลับมาใช้ใหม่ได้ (Design for Recycle) หรือถอดประกอบได้ง่าย (Design for Disassembly)
(6) ความเสี่ยง (Supplier risk)	(6.1) ความเสี่ยงจากธรรมชาติ (Natural risk)	โอกาสที่ประสิทธิภาพของผู้ส่งมอบจะไม่เป็นไปตามที่คาด อันเนื่องมาจากภัยธรรมชาติ และปัจจัยภายนอกที่ควบคุมไม่ได้
	(6.2) ความเสี่ยงจากความผิดพลาดของบุคคล (Human risk)	โอกาสที่ประสิทธิภาพของผู้ส่งมอบจะไม่เป็นไปตามที่คาดอันเนื่องมาจากความผิดพลาดของพนักงานของผู้ส่งมอบ

ส่วนที่ 1 ข้อมูลเบื้องต้นของผู้ตอบแบบสอบถาม

วันที่ตอบแบบสอบถาม: _____

ชื่อ:_____ นามสกุล:_____ ประสบการณ์ทำงาน: _____

เบอร์ติดต่อ: _____อีเมลล์: _____

ตำแหน่ง: _____บริษัท/หน่วยงาน:_____

- ประเภทบริษัท
  - ☐ บริษัทคนไทย
  - ☐ บริษัทร่วมทุนกับต่างชาติ โปรดระบุประเทศที่ร่วมทุน _____
  - ☐ บริษัทต่างชาติ ประเทศ (โปรดระบุ) _____
- ทุนจดทะเบียน
  - ☐ ไม่เกิน 50 ล้านบาท ☐ 51-200 ล้านบาท ☐ 200 ล้านบาทขึ้นไป
- จำนวนพนักงาน
  - ☐ ไม่เกิน 50 คน ☐ 51-200 คน ☐ 200 คนขึ้นไป
- วัตถุดิบหลัก (ที่เป็นชิ้นส่วน/อุปกรณ์ไฟฟ้าและอิเล็กทรอนิกส์) (โปรดระบุ)

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- ผลิตภัณฑ์หลัก (ที่เป็นชิ้นส่วน/อุปกรณ์ไฟฟ้าและอิเล็กทรอนิกส์) (โปรดระบุ)

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  _____
- การสั่งซื้อวัตถุดิบส่วนใหญ่สั่งซื้อจากภายใน หรือนำเข้าจากต่างประเทศ (โปรดระบุสัดส่วน)
  - สั่งซื้อจากภายในประเทศ _____%
  - นำเข้าจากต่างประเทศ _____%
- ผลิตภัณฑ์ส่วนใหญ่ขายภายในประเทศหรือส่งออกไปยังต่างประเทศ (โปรดระบุสัดส่วน)
  - ขายภายในประเทศ _____%
  - ส่งออกไปต่างประเทศ _____% (โปรดระบุประเทศ) _____

ส่วนที่ 2 การเปรียบเทียบน้ำหนักความสำคัญของปัจจัยต่าง ๆ

งานวิจัยนี้ต้องการทราบถึงน้ำหนักความสำคัญของปัจจัย ที่มีผลต่อการคัดเลือกผู้ส่งมอบ การประเมินคะแนนจึงใช้การเปรียบเทียบแบบคู่ (Pair-wise Comparison) เป็นส่วนใหญ่ ยกเว้นคำถามบางข้ออาจเป็นลักษณะเขียนตอบ โดยผู้ตอบแบบสอบถามสามารถพิจารณาจากระดับการให้ความสำคัญ ดังนี้

- 9 ปัจจัยหนึ่งมีความสำคัญกว่าอีกปัจจัยหนึ่งเป็นอย่างยิ่ง (Extreme Importance)
- 7 ปัจจัยหนึ่งมีความสำคัญกว่าอีกปัจจัยหนึ่งเป็นอย่างมาก (Very strong importance)
- 5 ปัจจัยหนึ่งมีความสำคัญกว่าอีกปัจจัยหนึ่งค่อนข้างมาก (Strong importance)
- 3 ปัจจัยหนึ่งมีความสำคัญกว่าอีกปัจจัยหนึ่งบ้าง (Moderate importance)
- 1 ปัจจัยทั้งสองมีความสำคัญเท่ากัน (Equal importance)
- 2, 4, 6, 8 อยู่กึ่งกลางระหว่างระดับที่กล่าวมาข้างต้น

ตัวอย่างการตอบแบบสอบถาม

- ในแต่ละแถวของแบบสอบถามนี้เป็นการเปรียบเทียบแบบคู่สำหรับ 2 ปัจจัย โดยปัจจัยแรกปรากฏทางคอลัมน์ซ้ายมือ ส่วนปัจจัยที่สองปรากฏทางคอลัมน์ขวามือ เช่น การเปรียบเทียบระหว่าง **“ต้นทุน”** และ **“คุณภาพ”** จากระดับการให้คะแนนข้างต้น สามารถประเมินคะแนนได้ดังตัวอย่างต่อไปนี้

ต้นทุน	(9)	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	คุณภาพ

- ตัวอย่างนี้หมายความว่า ในการคัดเลือกผู้ส่งมอบ “ต้นทุน” มี**น้ำหนักความสำคัญมากกว่า** “คุณภาพ” **เป็นอย่างยิ่ง**

ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	(5)	6	7	8	9	คุณภาพ

- ตัวอย่างนี้หมายความว่า “คุณภาพ” **มีน้ำหนักความสำคัญมากกว่า** “ต้นทุน” **ค่อนข้างมาก**

ต้นทุน	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	คุณภาพ

- ตัวอย่างนี้หมายความว่า “ต้นทุน” **มีน้ำหนักความสำคัญเท่ากับ** “คุณภาพ”

ข้อควรระวัง (เรื่องความสอดคล้องต่อเนื่องของการให้คะแนนภายใน 1 ชุดของตาราง)

ตัวอย่าง: พิจารณา **3** เกณฑ์ คือ ต้นทุน คุณภาพ และความสามารถในการส่งมอบ

ต้นทุน	9	8	(7)	6	5	4	3	2	1	2	3	4	5	6	7	8	9	คุณภาพ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	(9)	ความสามารถในการส่งมอบ
คุณภาพ	(9)	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ

- จากแถวที่ 1: “ต้นทุน” มีน้ำหนักความสำคัญมากกว่า “คุณภาพ” เป็นอย่างยิ่ง **[ต้นทุน > คุณภาพ]**
- จากแถวที่ 2: “ความสามารถในการส่งมอบ” มีน้ำหนักความสำคัญมากกว่า “ต้นทุน” เป็นอย่างยิ่ง **[ความสามารถในการส่งมอบ > ต้นทุน]**
- จาก 2 แถวแรก พบว่า **ความสามารถในการส่งมอบ > ต้นทุน > คุณภาพ** หรือ สามารถกล่าวได้ว่า “ความสามารถในการส่งมอบ” ต้องมีน้ำหนักความสำคัญมากกว่า “คุณภาพ” เป็นอย่างยิ่ง ด้วยเช่นกัน
- อย่างไรก็ตามแถวที่ 3 หมายความว่า “คุณภาพ” มีน้ำหนักความสำคัญมากกว่า “ความสามารถในการส่งมอบ” เป็นอย่างยิ่ง **[คุณภาพ > ความสามารถในการส่งมอบ] ซึ่งไม่สอดคล้องกับค่าของคะแนนใน 2 แถวแรก ในกรณีนี้จำเป็นต้องประเมินคะแนนใหม่**

- ตอนที่ 1: เปรียบเทียบความสำคัญของปัจจัยหลักที่มีผลต่อการตัดสินใจคัดเลือกผู้ส่งมอบโดยไม่คำนึงว่าแต่ละปัจจัยอาจส่งผลกระทบต่อกัน (แต่ละปัจจัยเป็นอิสระต่อกัน) เช่น คุณภาพอาจส่งผลต่อราคา ได้แก่ คำถามข้อ 1
- ตอนที่ 2: เปรียบเทียบความสำคัญของปัจจัยหลักที่มีผลต่อการตัดสินใจคัดเลือกผู้ส่งมอบโดยคำนึงว่าแต่ละปัจจัยหลักอาจส่งผลกระทบต่อกัน (แต่ละปัจจัยไม่เป็นอิสระต่อกัน) ได้แก่ คำถามข้อ 2-7
- ตอนที่ 3: เปรียบเทียบความสำคัญของปัจจัยรองที่มีต่อปัจจัยหลักแต่ละด้าน ได้แก่ คำถามข้อที่ 8-13
- ตอนที่ 4: เปรียบเทียบความสำคัญของปัจจัยรองที่มีต่อปัจจัยหลักแต่ละด้าน โดยคำนึงว่าแต่ละปัจจัยรองอาจส่งผลกระทบต่อกัน (แต่ละปัจจัยรองไม่เป็นอิสระต่อกัน) ได้แก่ คำถามข้อ 14-16
- ตอนที่ 5: เปรียบเทียบความสำคัญของปัจจัยรอง โดยคำนึงว่าแต่ละปัจจัยรองอาจส่งผลกระทบต่อปัจจัยรองอื่นภายนอกกลุ่ม (แต่ละปัจจัยรองไม่เป็นอิสระต่อกัน) ได้แก่ คำถามข้อ 17-28

คำถามที่ 1 ในการคัดเลือกผู้ส่งมอบ ท่านที่คิดว่าปัจจัยหลักใดมีน้ำหนักความสำคัญต่อการตัดสินใจเลือกผู้ส่งมอบมากกว่ากัน

ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	คุณภาพ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ผู้ส่งมอบสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง

คำถามที่ 2 ในการคัดเลือกผู้ส่งมอบ ท่านที่คิดว่าปัจจัยหลักใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักด้าน “**ต้นทุน**” มากกว่ากัน

คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ผู้ส่งมอบสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง

คำถามที่ 3 ในการคัดเลือกผู้ส่งมอบ ท่านที่คิดว่าปัจจัยหลักใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักด้าน “**คุณภาพ**” มากกว่ากัน

ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ผู้ส่งมอบสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง

คำถามที่ 4 ในการคัดเลือกผู้ส่งมอบ ท่านที่คิดว่าปัจจัยหลักใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักด้าน “**ความสามารถในการส่งมอบ**” มากกว่ากัน

ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	คุณภาพ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ผู้ส่งมอบสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง

คำถามที่ 5 ในการคัดเลือกผู้ส่งมอบ ท่านที่คิดว่าปัจจัยหลักใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักด้าน “**ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์**” มากกว่ากัน

ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	คุณภาพ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ผู้ส่งมอบสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง

คำถามที่ 6 ในการคัดเลือกผู้ส่งมอบ ท่านที่คิดว่าปัจจัยหลักใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักด้าน “**ผู้ส่งมอบสีเขียว**” มากกว่ากัน

ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	คุณภาพ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยง

คำถามที่ 7 ในการคัดเลือกผู้ส่งมอบ ท่านที่คิดว่าปัจจัยหลักใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักด้าน “**ความเสี่ยง**” มากกว่ากัน

ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	คุณภาพ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ต้นทุน	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการส่งมอบ
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
คุณภาพ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์
ความสามารถในการส่งมอบ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว
ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผู้ส่งมอบสีเขียว

คำถามที่ 8 สำหรับปัจจัยหลักด้าน “**ต้นทุน**” ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักดังกล่าวมากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ

คำถามที่ 9 สำหรับปัจจัยหลักด้าน “**คุณภาพ**” ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักดังกล่าวมากกว่ากัน

คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง

คำถามที่ 10 สำหรับปัจจัยหลักด้าน “**ความสามารถในการส่งมอบ**” ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักดังกล่าวมากกว่ากัน

ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา

คำถามที่ 11 สำหรับปัจจัยหลักด้าน “**ปัจจัยแวดล้อมของผู้ส่งมอบและความสัมพันธ์**” ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักดังกล่าวมากกว่ากัน

กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา

<u>คำถามที่ 12</u> สำหรับปัจจัยหลักด้าน “**ผู้ส่งมอบสีเขียว**” ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักดังกล่าวมากกว่ากัน

การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว

<u>คำถามที่ 13</u> สำหรับปัจจัยหลักด้าน “**ความเสี่ยง**” ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยหลักดังกล่าวมากกว่ากัน

ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

<u>คำถามที่ 14</u> ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**กำลังการผลิตและความยืดหยุ่น**” มากกว่ากัน

ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา

<u>คำถามที่ 15</u> ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ความสามารถทางด้านเทคนิค**” มากกว่ากัน

กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา

<u>คำถามที่ 16</u> ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ความร่วมมือในการพัฒนา**” มากกว่ากัน

กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค

<u>คำถามที่ 17</u> ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ราคา**” มากกว่ากัน

คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

<u>คำถามที่ 18</u> ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ต้นทุนอื่น ๆ** ” มากกว่ากัน

คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

<u>คำถามที่ 19</u> ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 20 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ความสามารถในการปรับปรุงอย่างต่อเนื่อง**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 21 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ระยะเวลานำในการสั่งซื้อ**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 22 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**อัตราการส่งมอบตรงเวลา**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 23 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**กำลังการผลิตและความยืดหยุ่น**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 24 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ความสามารถทางด้านเทคนิค**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว

ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 25 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ความร่วมมือในการพัฒนา**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 26 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**การผลิตสีเขียว**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 27 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ผลิตภัณฑ์และการออกแบบสีเขียว**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความเสี่ยงจากธรรมชาติ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความเสี่ยงจากความผิดพลาดของบุคคล

คำถามที่ 28 ท่านที่คิดว่าปัจจัยรองใดต่อไปนี้มีผลกระทบต่อปัจจัยรองด้าน “**ความเสี่ยงจากความผิดพลาดของบุคคล**” มากกว่ากัน

ราคา	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ต้นทุนอื่น ๆ
คุณภาพของผลิตภัณฑ์และความน่าเชื่อถือ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถในการปรับปรุงอย่างต่อเนื่อง
ระยะเวลานำในการสั่งซื้อ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการส่งมอบตรงเวลา
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสามารถทางด้านเทคนิค
กำลังการผลิตและความยืดหยุ่น	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
ความสามารถทางด้านเทคนิค	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความร่วมมือในการพัฒนา
การผลิตสีเขียว	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ผลิตภัณฑ์และการออกแบบสีเขียว

ส่วนที่ 3 การประเมินประสิทธิภาพของผู้ส่งมอบในด้านต่าง ๆ

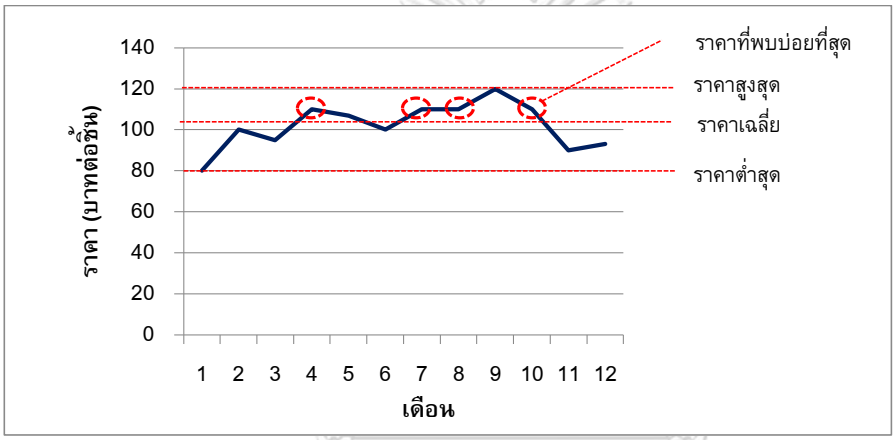
ในส่วนนี้ ขอให้ผู้ตอบแบบสอบถามนึกถึงผู้ส่งมอบในปัจจุบัน จำนวน 2 ราย ที่ทำการส่งมอบวัตถุดิบประเภทเดียวกันให้ท่าน ทั้งนี้ เพื่อเป็นการรักษาความลับขององค์กร ท่านไม่จำเป็นต้องเปิดเผยชื่อผู้ส่งมอบ โดยผู้ส่งมอบแต่ละรายจะถูกแทนชื่อด้วย “ผู้ส่งมอบ A” และ “ผู้ส่งมอบ B” แบบสอบถามส่วนนี้แบ่งเป็น 3 ตอน ดังนี้

- ตอนที่ 1 การตัดสินใจเลือกซื้อวัตถุดิบจากผู้ส่งมอบ A และ B
- ตอนที่ 2 การประเมินประสิทธิภาพของผู้ส่งมอบ A
- ตอนที่ 3 การประเมินประสิทธิภาพของผู้ส่งมอบ B

ทั้งนี้ในการประเมินประสิทธิภาพขอให้ท่านเลือกวัตถุดิบ 1 รายการที่สั่งจากผู้ส่งมอบทั้ง 2 โดยต้องอ้างอิงจากวัตถุดิบชนิดเดียวกัน ในการประเมินสำหรับปัจจัยแต่ละด้านนั้นจะประเมินประสิทธิภาพ 4 ค่า ได้แก่

- ค่าเฉลี่ย หรือภาพรวมของประสิทธิภาพที่ผ่านมา
- ค่าต่ำสุด หรือ ระดับของประสิทธิภาพที่ต่ำที่สุดที่เคยเกิดขึ้นกับผู้ส่งมอบนั้น
- ค่าสูงสุด หรือ ระดับของประสิทธิภาพที่สูงที่สุดที่เคยเกิดขึ้นกับผู้ส่งมอบนั้น
- ค่าที่เกิดขึ้นบ่อย หรือ ระดับของประสิทธิภาพที่เกิดขึ้นบ่อยที่สุดของผู้ส่งมอบนั้น

ตัวอย่าง: การประเมินประสิทธิภาพปัจจัยด้านราคา จากราคาวัตถุดิบของผู้ส่งมอบที่ผ่านมาเป็นระยะเวลา 1 ปี



ตอนที่ 1 การตัดสินใจเลือกซื้อวัตถุดิบจากผู้ส่งมอบ A และ B

ระหว่างผู้ส่งมอบ A และ B ที่ขายวัตถุดิบประเภทเดียวกับให้กับองค์กรของท่าน หากอ้างอิงจากประสิทธิภาพโดยรวมในอดีตที่ผ่านมา ท่านจะเลือกซื้อจากผู้ส่งมอบใด

☐ ผู้ส่งมอบ A ☐ ผู้ส่งมอบ B

ตอนที่ 2 การประเมินประสิทธิภาพของผู้ส่งมอบ A

	ราคาเฉลี่ย	ราคาต่ำที่สุด	ราคาสูงที่สุด	ความผันผวนของราคา
ราคาต่อชิ้น (บาทต่อชิ้น)				โดยส่วนใหญ่ ราควัตถุดิบจากผู้ส่งมอบ A ที่ผ่านมาเมื่อเทียบกับราคาเฉลี่ย: ☐ ไม่ต่างกัน ☐ ถูกกว่า มีราคาประมาณ _____บาท ☐ แพงกว่า มีราคาประมาณ _____บาท

	ค่าใช้จ่ายต่อครั้งเฉลี่ย	ค่าใช้จ่ายต่อครั้งต่ำสุด	ค่าใช้จ่ายต่อครั้งสูงสุด	ความผันผวนของค่าใช้จ่ายอื่น ๆ ในการสั่งซื้อ
ค่าใช้จ่ายอื่น ๆ ในการสั่งซื้อต่อครั้ง (บาทต่อครั้ง)				โดยส่วนใหญ่ ต้นทุนอื่น ๆ ในการสั่งซื้อจากผู้ส่งมอบ A ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย: ☐ ไม่ต่างกัน ☐ ถูกกว่า มีต้นทุนประมาณ_____บาท ☐ แพงกว่า มีต้นทุนประมาณ_____ บาท

	อัตราการถูกตีกลับเฉลี่ย	อัตราการถูกตีกลับต่ำสุด	อัตราการถูกตีกลับสูงสุด	ความผันผวนของอัตราการถูกตีกลับ
อัตราการถูกตีกลับ (Return rate%) (%)				โดยส่วนใหญ่ อัตราการถูกตีกลับวัตถุดิบของผู้ส่งมอบ A ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย: ☐ ไม่ผันผวน ☐ ต่ำกว่า มีอัตราตีกลับประมาณ_____% ☐ แพงกว่า มีอัตราตีกลับประมาณ_____%

	ระยะเวลานำเฉลี่ย	ระยะเวลานำสั้นสุด	ระยะเวลานำยาวสุด	ความผันผวนของระยะเวลานำในการสั่งซื้อ
ระยะเวลานำในการสั่งซื้อ (Lead time) (วัน)				โดยส่วนใหญ่ ระยะเวลานำในการสั่งซื้อจากผู้ส่งมอบ A ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย: ☐ ไม่ผันผวน ☐ สั้นกว่า มีระยะเวลานำประมาณ_____วัน ☐ แพงกว่า มีระยะเวลานำประมาณ_____วัน

	อัตราการส่งมอบเฉลี่ย	อัตราการส่งมอบต่ำสุด	อัตราการส่งมอบสูงสุด	ความผันผวนของอัตราการส่งมอบตรงเวลา
อัตราการส่งมอบตรงเวลา (On-time delivery) (%)				โดยส่วนใหญ่ อัตราการส่งมอบตรงเวลาของผู้ส่งมอบ A ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย: ☐ ไม่ผันผวน ☐ ต่ำกว่า มีอัตราการส่งมอบประมาณ____% ☐ สูงกว่า มีอัตราการส่งมอบประมาณ_____%

สำหรับปัจจัยต่อไปนี้ ขอให้ท่านประเมินประสิทธิภาพของผู้ส่งมอบ A โดยการให้คะแนนตั้งแต่ 0-99 คะแนน โดย คะแนน 0 หมายถึงประสิทธิภาพต่ำและเป็นที่ไม่พึงพอใจเป็นอย่างมาก คะแนน 99 หมายถึงประสิทธิภาพสูงและเป็นที่พึงพอใจเป็นอย่างมาก

	คะแนนเฉลี่ย	คะแนนต่ำสุด	คะแนนสูงสุด	ความผันผวนของคะแนนความพึงพอใจ โดยส่วนใหญ่ คะแนนความพึงพอใจที่ท่านมีต่อผู้ส่งมอบ A ของแต่ละปัจจัย ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย:
ความสามารถในการปรับปรุงอย่างต่อเนื่อง				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
กำลังการผลิตและความยืดหยุ่น				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
ความสามารถทางด้านเทคนิค				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
ความร่วมมือในการพัฒนา				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
ความใส่ใจต่อการผลิตสีเขียว				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
ความใส่ใจต่อผลิตภัณฑ์และการออกแบบสีเขียว				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
การรับมือกับความเสี่ยงจากธรรมชาติ				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
การรับมือกับความผิดพลาดของบุคคล				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน

ตอนที่ 3 การประเมินประสิทธิภาพของผู้ส่งมอบ B

	ราคาเฉลี่ย	ราคาต่ำที่สุด	ราคาสูงที่สุด	ความผันผวนของราคา
ราคาต่อชิ้น (บาทต่อชิ้น)				โดยส่วนใหญ่ ราคาวัตถุดิบจากผู้ส่งมอบ B ที่ผ่านมาเมื่อเทียบกับราคาเฉลี่ย: ☐ ไม่ต่างกัน ☐ ถูกกว่า มีราคาประมาณ _____บาท ☐ แพงกว่า มีราคาประมาณ _____บาท

	ค่าใช้จ่ายต่อครั้งเฉลี่ย	ค่าใช้จ่ายต่อครั้งต่ำสุด	ค่าใช้จ่ายต่อครั้งสูงสุด	ความผันผวนของค่าใช้จ่ายอื่น ๆ ในการสั่งซื้อ
ค่าใช้จ่ายอื่น ๆ ในการสั่งซื้อต่อครั้ง (บาทต่อครั้ง)				โดยส่วนใหญ่ ต้นทุนอื่น ๆ ในการสั่งซื้อจากผู้ส่งมอบ B ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย: ☐ ไม่ต่างกัน ☐ ถูกกว่า มีต้นทุนประมาณ_____บาท ☐ แพงกว่า มีต้นทุนประมาณ_____ บาท

	อัตราการถูกตีกลับเฉลี่ย	อัตราการถูกตีกลับต่ำสุด	อัตราการถูกตีกลับสูงสุด	ความผันผวนของอัตราการถูกตีกลับ
อัตราการถูกตีกลับ (Return rate%) (%)				โดยส่วนใหญ่ อัตราการถูกตีกลับวัตถุดิบของผู้ส่งมอบ B ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย: ☐ ไม่ผันผวน ☐ ต่ำกว่า มีอัตราตีกลับประมาณ_____% ☐ แพงกว่า มีอัตราตีกลับประมาณ_____%

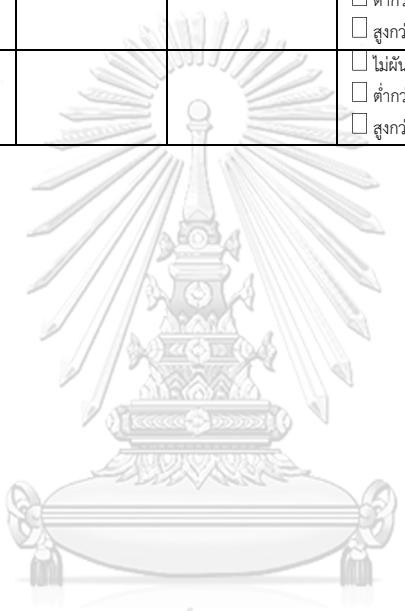
	ระยะเวลานำเฉลี่ย	ระยะเวลานำสั้นสุด	ระยะเวลานำยาวสุด	ความผันผวนของระยะเวลานำในการสั่งซื้อ
ระยะเวลานำในการสั่งซื้อ (Lead time) (วัน)				โดยส่วนใหญ่ ระยะเวลานำในการสั่งซื้อจากผู้ส่งมอบ B ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย: ☐ ไม่ผันผวน ☐ สั้นกว่า มีระยะเวลานำประมาณ_____วัน ☐ แพงกว่า มีระยะเวลานำประมาณ_____วัน

	อัตราการส่งมอบเฉลี่ย	อัตราการส่งมอบต่ำสุด	อัตราการส่งมอบสูงสุด	ความผันผวนของอัตราการส่งมอบตรงเวลา
อัตราการส่งมอบตรงเวลา (On-time delivery) (%)				โดยส่วนใหญ่ อัตราการส่งมอบตรงเวลาของผู้ส่งมอบ B ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย: ☐ ไม่ผันผวน ☐ ต่ำกว่า มีอัตราการส่งมอบประมาณ_____% ☐ สูงกว่า มีอัตราการส่งมอบประมาณ_____%

สำหรับปัจจัยต่อไปนี้ ขอให้ท่านประเมินประสิทธิภาพของผู้ส่งมอบ B โดยการให้คะแนนตั้งแต่ 0-99 คะแนน โดย คะแนน 0 หมายถึงประสิทธิภาพต่ำและเป็นที่ไม่พึงพอใจเป็นอย่างมาก คะแนน 99 หมายถึงประสิทธิภาพสูงและเป็นที่พึงพอใจเป็นอย่างมาก

	คะแนนเฉลี่ย	คะแนนต่ำสุด	คะแนนสูงสุด	ความผันผวนของคะแนนความพึงพอใจ โดยส่วนใหญ่ คะแนนความพึงพอใจที่ท่านมีต่อผู้ส่งมอบ A ของแต่ละปัจจัย ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย:
ความสามารถในการปรับปรุงอย่างต่อเนื่อง				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
กำลังการผลิตและความยืดหยุ่น				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
ความสามารถทางด้านเทคนิค				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน

	คะแนนเฉลี่ย	คะแนนต่ำสุด	คะแนนสูงสุด	ความผันผวนของคะแนนความพึงพอใจ โดยส่วนใหญ่ คะแนนความพึงพอใจที่ท่านมีต่อผู้ส่งมอบ A ของแต่ละปัจจัย ที่ผ่านมาเมื่อเทียบกับค่าเฉลี่ย:
ความร่วมมือในการพัฒนา				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
ความใส่ใจต่อการผลิตสีเขียว				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
ความใส่ใจต่อผลิตภัณฑ์และการออกแบบสีเขียว				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
การรับมือกับความเสี่ยงจากธรรมชาติ				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน
การรับมือกับความผิดพลาดของบุคคล				☐ ไม่ผันผวน ☐ ต่ำกว่า มีคะแนนประมาณ_____คะแนน ☐ สูงกว่า มีคะแนนประมาณ_____คะแนน



VITA

Ornicha Anuchitchanchai was born and raised in Chiang Rai. After graduation from Samakkhiwitthayakhom School, she attended Chiang Mai University and received her Bachelor of Industrial Engineering in 2001. She began her career as production engineer at LTEC Ltd. in Northern Region Industrial Estate. After working there for one and a half year, she resigned for further study at Chulalongkorn University and earned Master's Degree in Industrial Engineering in 2006. She have been working as a lecturer in Industrial and Logistics Engineering since then. She also had professional experiences in logistics consultant of Bureau of Logistics, Department of Primary Industries and Mines for years.