APPLICATION OF THE ANALYTIC HIERARCHY PROCESS (AHP) TO SET UP THE SUPPLIER SELECTION CRITERIA OF A PIPELINE TRADING COMPANY

By

PLOYPAIJIT POKKASAP

A Final Report of the Six-Credit Course
SCM 7203 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
Assumption University
Bangkok, Thailand

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Martin de Tours School of Management and Economics
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August 2014

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Master of Science in Supply Chain Management

Declaration of Authorship Form

I, Ms.Ploypaijit Pokkasap declare that this thesis/project and the work presented in it are my own and has been generated by me as the result of my own original research.

APPLICATION OF THE ANALYTIC HIERARCHY PROCESS (AHP) TO SET UP THE SUPPLIER SELECTION CRITERIA OF A PIPELINE TRADING COMPANY

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I confirm that this thesis/project has been carried out under my supervision and it represents the original work of the candidate.

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(Asst. Prof. Dr. Nucharee Supatn)

Date Aug 30, 2014

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I would never have been able to complete this study successfully without the help and support from many people directly and indirectly involved in this work.

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Ploypaijit Pokkasap
Assumption University
August 2014

ABSTRACT

Supplier selection and evaluation are claimed as one of the most important functions for the success of an organization. An improper selection and evaluation of the right supplier can obstruct supply chain performance. The objective of this study is to present an efficient methodology for evaluating and selecting suppliers in a pipeline trading company in Thailand. Specifically, the study is applied to the Analytic Hierarchy Process to select the most appropriate source of supply.

In the literature review of criteria the study identified that quality, delivery, performance history and warranty policy are the most important criteria for supplier selection. However, the study used the four criteria of price, quality, delivery and warranty as the most important criteria in supplier selection, of which these four criteria were ranked by six experts in the pipeline of ABC Company. Then, the pipeline suppliers from China, Korea and Singapore were evaluated against the mentioned criteria.

The results indicated that price selection criterion is the most important, followed by quality, delivery and warranty. Regarding the supplier selection, the findings suggested that the supplier from Singapore should be selected since its overall performance is the best among the pipeline suppliers even though its performance in price offered is the lowest.

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I, Michael Welch, have proofread this thesis/project entitled APPLICATION OF THE ANALYTIC HIERARCHY PROCESS (AHP) TO SET UP THE SUPPLIER SELECTION CRITERIA OF A PIPELINE TRADING COMPANY

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Signed _____

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Date: _____

CHAPTER I

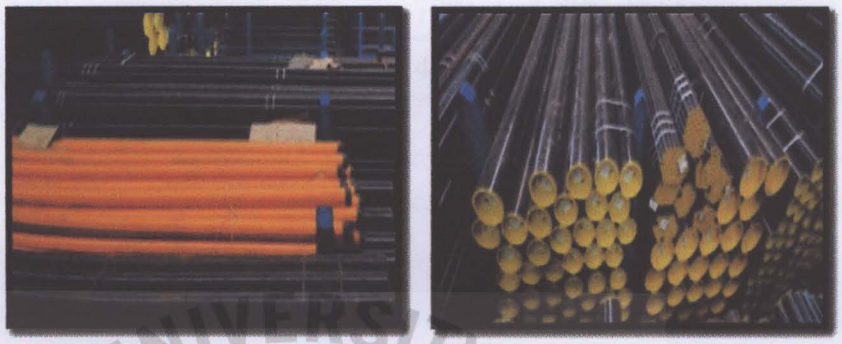
GENERALITIES OF THE STUDY

Over the last decade, supply chain management has influenced businesses all over the globe. Purchasing is one function of the supply chain which is important to add value to the products or services. It is recognized that selecting appropriate suppliers is the major aspect of purchasing tasks and also one of the key success factors of a firm as well. However, the right supplier selection is always tough for a purchasing manager (Liu & Hai, 2005). Selecting the right suppliers can lead the company to gain more competitive advantages and get business success. On the contrary, the wrong supplier selection can lead to excessive costs to the company and, consequently, end up with financial problems. Therefore, the company needs to emphasize supplier performance evaluation in order to select the right suppliers who are suitable to the company. Concerning on only one criterion such as price may be insufficient to select the most suitable suppliers. Thus, multi criteria for evaluating suppliers must be simultaneously considered in order to select the appropriate supplier.

1.1 Background of the Study

Nowadays, the oil and gas industry plays a major role in driving business in both a local and global level. It provides energy and essential chemicals for industry, homes and transport which is increasingly consumed by users every day. There are around fifty oil and gas companies located in Thailand and ten out of fifty are ABC Company's customers. The ABC Company is one of the leading trading, stockist, sole distributors and engineering companies who supply industrial process equipment of piping materials; for instance pipeline, flanges and fittings. The Company was established in May, 1998 with 100% Thai shareholders. The company caters the materials and supplies to the oil and gas industry in order to construct and maintain transmission pipeline projects and shutdown plants.

Figure 1.1: Piping Material of ABC Company

Description	Picture
Pipeline	
Flange	
Fitting	

Source: ABC Company

The Company is growing gradually at 4.42% in trading materials, likewise the purchasing amount is also incessantly increased to 11.87%. The increase in purchasing is from the company being committed to stocking materials in order to supply anytime when they need to fulfill the customer's satisfaction. Table 1.1 shows the comparison of sales data and purchase data from 2012 to 2013 of the ABC Company.

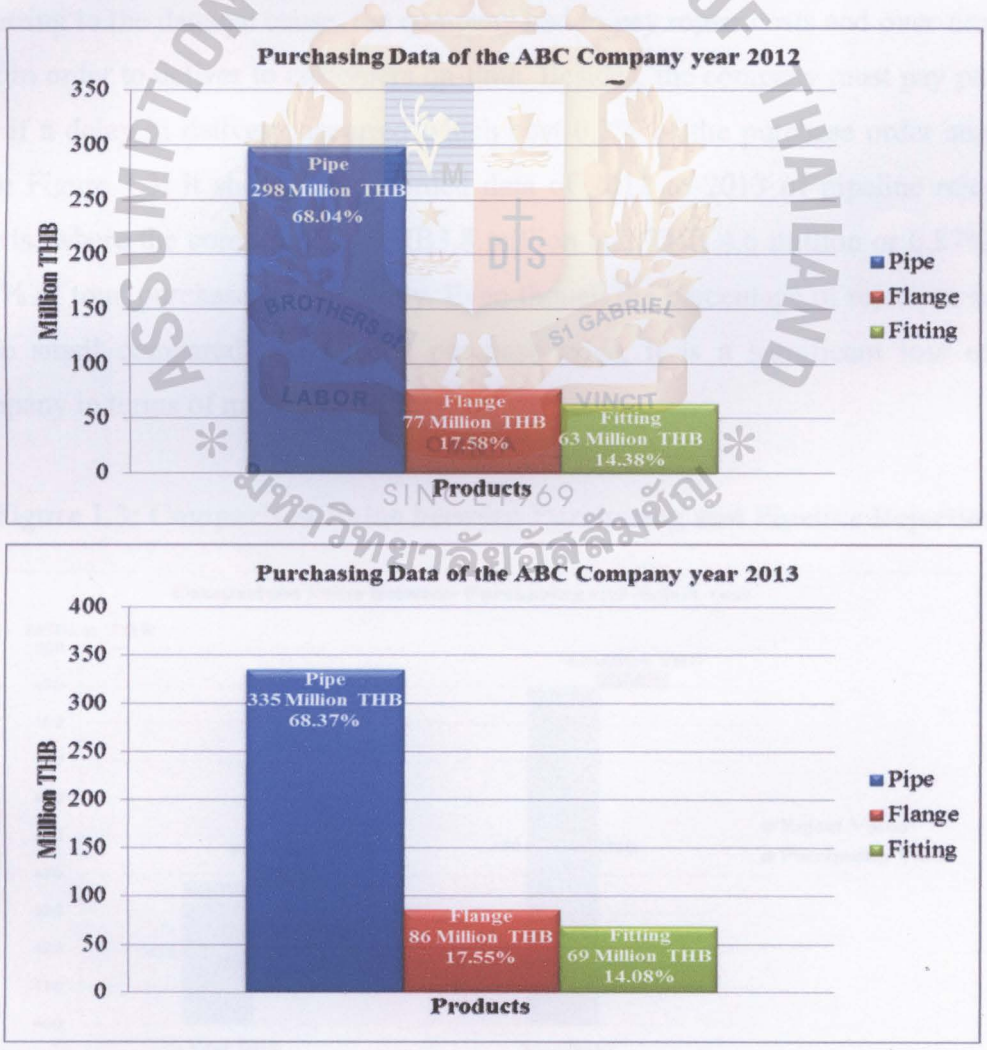
Table 1.1: Sales and Purchasing Data of the ABC Company

	Year		% Increase
	2012	2013	
Total Sales (Million THB)	747	780	4.42% (33 Million THB)
Total Purchasing (Million THB)	438	490	11.87% (52 Million THB)

Source: ABC Company

During the year, the ABC Company has to purchase piping materials which are composed of pipelines, flanges and fittings as the proportions show in figure 1.2.

Figure 1.2: Purchasing Proportion of the ABC Company



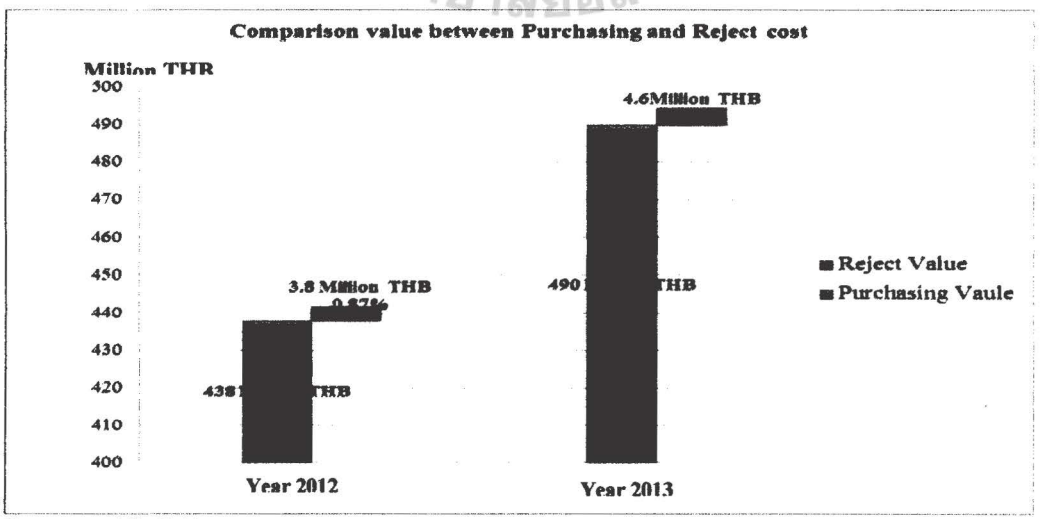
Source: ABC Company

From Figure 1.2, the amount purchased by ABC Company from 2012 to 2013 of pipelines, flanges and fittings are approximately equal to 68%, 18% and 14% respectively. The purchased amount of pipelines is much higher than others materials.

1.2 Statement of the Problem

According to the pipeline rejection report which was recorded in the system of ABC Company, the researcher found the problems of purchasing process which should be improved and it might be useful for the company. In every year, the company has lost costs which directly affect the company's revenue. Regarding the pipeline rejection report, it has shown that the company lost cause from damage and late delivery. Referring to the damage cause, the company had to pay repair costs and over-time for staff in order to deliver to customers on-time. Besides, the company must pay penalty fees if a delay in delivery occurred which cost 0.2% of the purchase order amount. From Figure 1.3, it shows the recorded data of 2012 to 2013 of pipeline rejection reports, where the company lost THB3.8 million and THB 4.6 million or 0.87% and 0.94% of total purchases respectively. Even though the percentage of rejection seems to be small compared to the total purchase price, it is a significant loss of the Company in terms of monetary value.

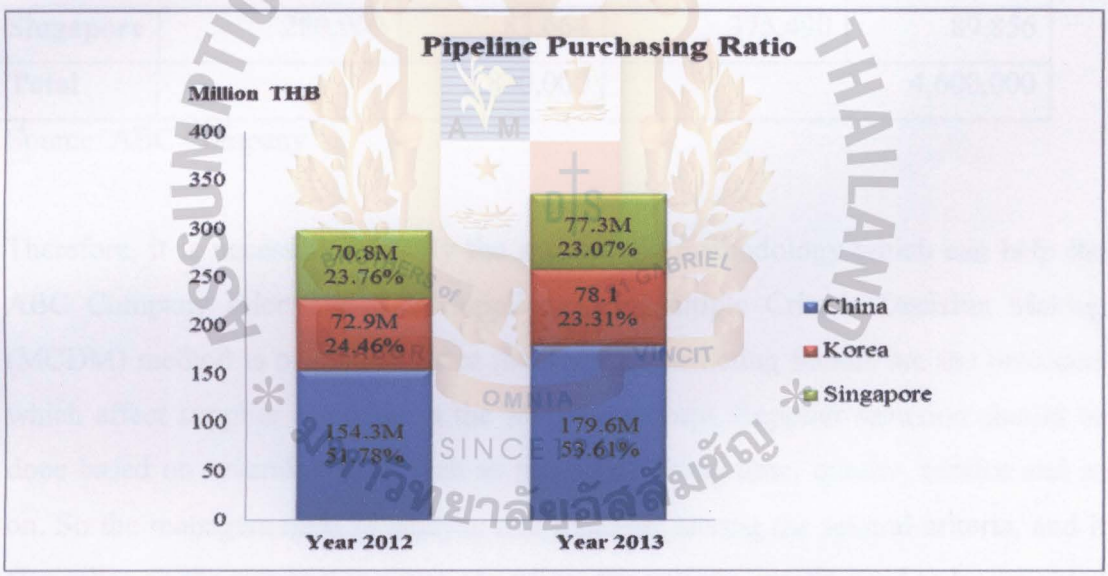
Figure 1.3: Comparison Value between Purchasing and Pipeline Rejection



Source: ABC Company

ABC Company, currently, has three suppliers supplying pipeline products using for the oil and gas industry. All are oversea suppliers from Korea, Singapore and China. At the present, the Company does not have any general model for supplier selection and uses only price to select the supplier regardless of other criteria. The supplier who offers the lowest bidding quotation is then selected. The ratios of pipeline purchasing from three suppliers are shown in figure 1.4. The highest spent is approximately 53% for Chinese suppliers because they normally offered the most competitive price, whereas for Korean suppliers and Singaporean suppliers, they are almost equal at 23.5%.

Figure 1.4: Purchasing Value of Pipeline to Each Supplier



Source: ABC Company

However, the 2012-2013 data indicated the inappropriate selection of the suppliers since some problems from pipeline rejection are illustrated. Table 1.2 shows lost costs of 2012 to 2013 from pipeline damage and late delivery costs of suppliers from China, Korea and Singapore. Chinese suppliers are mostly offered the competitive price rather than other suppliers, but the quality is quite lower than Korea and Singapore which can be seen in the record where the highest amount was spent on repairing and overtime. Referring to Chinese suppliers in 2012 to 2013, the company has lost for

repairing and overtime costs more than THB 2 Million a year while the penalty costs were about THB 800 Thousand a year. The performance of suppliers from Korea and Singapore are better than Chinese suppliers in terms of the damage and late delivery rates, which are shown in Table 1.2. However, Korean and Singaporean suppliers are frequency offered at higher bids than Chinese which also effects the margin.

Table 1.2: ABC Company's Losing Cost Respect to Supplier

	Year 2012		Year 2013	
	Repairing and Overtime (THB)	Late Delivery (THB)	Repairing and Overtime (THB)	Late Delivery (THB)
China	2,142,796	836,640	2,711,900	887,328
Korea	330,504	125,496	389,410	146,016
Singapore	280,900	83,664	375,490	89,856
Total		3,800,000		4,600,000

Source: ABC Company

Therefore, it is necessary to apply the appropriate methodology which can help the ABC Company select the right supplier. The Multiple Criteria Decision Making (MCDM) method is of interest since the several conflicting factors are the problems which affect supplier selection in the MCDM concept. Supplier selection should be done based on several criteria such as price, delivering time, quality, service and so on. So the managers need to analyze and trade-off among the several criteria, and it also relies on the purchasing situations where the various criteria need to be weighted in order to select the critical one to be considered to purchase. There are many evaluation models in literature for instance total cost of ownership (TCO), linear-weighting (LW) and mathematical programming, where it is obvious that the LW model does not include quantitative factors such as delivery and price, while the mathematical programming (MP) model does not include qualitative factors such as customer service and finance (De Bore, Wegen & Telgen, 1998; Ghodsypour & O'Brien, 1998). To evaluate supplier performance efficiently, it is essential to identify qualitative and quantitative criteria (Weber, Current & Benton, 1991).

Analytic Hierarchy Process (AHP) is one effective strategy for supplier evaluation which is wildly used successfully in multifactor decision making circumstances where all criteria are weighted based on pair-wise comparisons. The AHP methodology elicits both quantitative as well as qualitative analysis to reach a desired objective (David, Jonathan & Samuel, 2012). AHP has the ability to structure complex, multi-attribute, multi-person and multi-period problems hierarchically (Yusuff, PohYee & Hashmi, 2001). This method can be useful when it is involved in various decision makers with conflicting objectives to work out as a consensus. It is recognized that the AHP method can support decision making to solve the supplier selection problem in an optimal supplier combination selection (Yu & Jing, 2004). Hence, this study aims to answer the question ***"How would the ABC Company apply the AHP to identify the supplier selection criteria?"***. It would help the ABC Company to completely understand the perspective supplier's evaluation then the company can apply to select the right supplier.

1.3 Research Objectives

This study is attended on three objectives which are:

1. To apply the Analytic Hierarchy Process (AHP) model to identify the essential criteria and select the appropriate pipeline's suppliers for ABC Company.
2. To set up the procedure for ABC Company to apply AHP in supplier selection process.

1.4 Scope of the Research

This study focuses on the evaluation of multiple criteria by using the AHP method to evaluate the various criteria for supplier selection of ABC Company. The study is regardless of focus on customer satisfaction, increasing sales value or decreasing inventory. Three suppliers will be evaluated and scored. All criteria will be weighted and scored by pairwise comparison by all personnel of the purchasing department which is composed of one purchasing manager and two purchasing staff, who have

knowledge and experience relevant with pipeline products of ABC Company and contact directly with oversea suppliers. The position and experience of the decision makers is shown in Table 1.3.

Table 1.3: Position and Work Experience of Decision Makers

Number	Position	Work experience with the company (year)
1	Purchasing Manager	7
2	Purchasing staff	3
3	Purchasing staff	1

In the computation process, the rounding function in Microsoft excel with four decimals will be applied. The emphasis of the study is limited to one particular pipeline trading company in Thailand. Therefore, this study is not strong enough to be standardized to all Thai pipeline trading companies.

1.5 Significance of the Research

This study aims to apply the AHP method to improve the supplier selection process by muti-criteria decision for ABC Company. The AHP is a logical evaluation method to select the appropriate supplier leading to an increase in customer satisfaction and the company's revenue. Therefore, the result of this study will benefit the company not only for pipeline products but also to be applied to be used with the others kinds of high value products. Besides, this study will be beneficial to the company in a way where it provides a better method than the existing purchasing procedure, and also serves the Company as the basis of a systematic method and a theoretical model for future analysis and selecting suppliers based on multi-criteria decision making.

1.6 Limitations of the Research

This study is primarily limited by the information database of ABC Company. Unfortunately, in year 2011 the SAP system of the company failed and resulted in all recorded data being lost and the system could not recover the data. Thus, in this study

it will bring the available recorded data only from 2012 onward to 2013. Secondly, almost all pipeline suppliers supply from overseas, thereby the monetary units will not be the same and also the currency exchange fluctuated from 2012 to 2013. Lastly, the study pertains only to pipeline supplier selection criteria for ABC Company. The criteria evaluated the results which may differ depending on management, type of products and business style of each organization.

1.7 Definition of Terms

Analytic Hierarchy Process (AHP)	is the method based from mathematics, which allows companies to solve multi-criteria situations by weight score on the considered criteria (Saaty, 2000).
Linear weighting	is the model used for evaluating the potential suppliers by using several equally weighted factors and the supplier who has the highest score will be chosen by decision the maker (Timmerman, 1986).
Multiple Criteria Decision Making (MCDM)	is considered by more than one characterization as a choice among alternatives factors (Dickson, 1966).
Pair-wise comparison	is the process of comparing and evaluating alternatives or a group of items by assigning weights on decision making criteria (Saaty, 2000).
Supplier performance evaluation	is a process used for measuring and approving potential suppliers (Dickson, 1966).
Supplier Selection	is the process in which the company identifies, evaluates and contracts with suppliers (Saaty,

2000).

TCO	is a methodology which expresses beyond the price of a purchase to include many other purchase-related items (Bhutta & Huq , 2002).
Trade-off	is a situation two factors need to be chosen where only one is regarded as more necessary (Bhutta & Huq , 2002).

CHAPTER II

REVIEW OF RELATED LITERATURE

Supplier selection is recognized as an important decision making process in supply chain management. It is obvious that the selection of suitable suppliers and effective supplier relationship management are crucial factors to encourage the competitiveness of companies (Davis, 1993; Ghodsypour & O'Brien, 2001; Hines, 1994; Choy, Lee & Lo, 2003). For the following reasons, the companies are required to evaluate the supplier performance periodically in terms of several critical criteria (Mummalaneni, Dubas & Chao, 1996).

Generally, supplier selection has a large evaluation processes. All suppliers are evaluated on several criteria for instance price, delivery, quality and service. Normally, the evaluation criteria will relate with trade-offs for example one supplier may offer the cheaper price with the slightly lower quality whereas the other supplier may offer better quality products on late delivery. Therefore, these kinds of criteria are important for making decisions that are quantitative such as price, quality and qualitative such as service and flexibility which varies from each company.

2.1 Supplier Selection Criteria

The principle manner of the procurement department is supplier selection. Selecting the right supplier and constructing the criteria are necessary for the organization in order to determine the supplier's performance. Around mid-1960, there were many scientists and researchers who studied this issue and developed different methods to selecting the required criteria that could be appropriate tools to use in supplier evaluation.

Dickson (1966) is the first researcher who extends the knowledge on supplier criteria which can identify and use in supplier selection in a company. The study was referent on 273 questionnaires that were sent to a purchasing agent and a purchasing manager from United States and Canada. The questionnaire was ranked into a five point scale from extreme, considerable, average, slight and of no importance. Then, the study came up with 23 criteria which are shown in Table 2.1. The most significant criteria of this study are quality, delivery, performance history and warranty policy respectively.

Table 2.1: Dickson's Supplier Selection Criteria

Rank	Criteria	Evaluation
1	Quality	Extreme Importance
2	Delivery	
3	Performance History	
4	Warranty Policy	
5	Production Facilities and Capacity	Considerable Importance
6	Price	
7	Technical Capability	
8	Financial Position	
9	Procedural Compliance	
10	Communication System	
11	Reputation and Position in Industry	
12	Desire for Business	
13	Management and Organization	
14	Operating Controls	
15	Repair Service	Average Importance
16	Attitude	
17	Impression	
18	Packing Ability	
19	Labor Relations Record	
20	Geographical and Location	
21	Amount of Past Business	
22	Training aids	
23	Reciprocal Agreement	Slight Importance

Source: Dickson (1966)

Weber, Current and Benton (1991) studied 74 articles of the supplier selection criteria retail environments and manufacturing. The research used Dickson's 23 criteria to analyze and rank the supplier selection criteria and exposed that price, delivery and quality were respected in 80%, 59% and 54% of the reviewed articles respectively, and these three criteria were ranked as having extreme or considerable importance by Dickson. Furthermore, production facilities capability and technical capability were

respected in 31% and 20% of the reviewed articles respectively, and were ranked as having considerable importance by Dickson. Geographical location was respected in 22% of the reviewed articles and was ranked as having an average importance. As stated by the researcher, several criteria for instance warranties and claim policies, impression, communication system, labor relations record, reciprocal agreement and amount of past business have received less attention in the past five years.

Deng and Wortzel (1995) studied on supplier selection criteria used by US importers in three merchandise categories. For all three categories, the most important criteria were price, quality and delivery respectively. Ghodsypour and O'Brien (1998) consented that price, quality and service are the three major categories when deciding supplier selection parameters. Karpak, Kumcu and Kasuganti (2001) also considered price, quality and delivery as supplier selection criteria in the research.

The study of Zhang, Lei, Cao and Ng (2003) was performed based on 23 criteria of Dickson's (1966) study and the Weber, Current and Benton (1991) study. The study showed that quality, price and delivery were the major importance for the supplier selection criteria. So, the important criteria for supplier selection which was presented in the literature was already mentioned above can be summarized in the table 2.2

Table 2.2: Summaries the Important Criteria for Supplier Selection

Selection Criteria	A	B	C	D	E	F
Price		√	√	√	√	√
Quality	√	√	√	√	√	√
Delivery	√	√	√		√	√
Warranty Policy	√					
Service				√		
Performance History	√					

Note: A = Dickson (1966);
B = Weber et al. (1991);
C = Deng et al. (1995);
D = Ghodsypour et al.(1998);
E = Karpak et al. (2001);
F = Zhang et al.(2003);

2.2 Supplier Selection Approach

Currently, many companies still consider the cost as a principal concern in purchasing, meanwhile new ideas about multiple-criteria are being used increasingly in some companies. A summary about the supplier selection approaches which are available in literature are presented as follows:

2.2.1 Linear Weighting (LW)

The LW model evaluates the potential supplier by using several equally weighted factors and the supplier who has the highest score will be chosen by the decision maker (Timmerman, 1986). Normally, this method is designed with quantitative measurement but it is difficult to effectively review qualitative evaluation criteria. This model weighted the criteria equally which seldom happens in practice (Min, 1994 ; Ghodsypour & O'Brien, 1998). All criteria are weighted by the decision maker which on a zero (less important) to one (most important) scale.

In contrary to an equal weighting applied in the LW model, AHP is more effective method because it utilizes pairwise comparison for the best supplier selection. There are many researchers using AHP to deal with supplier selection problem such as Nydick and Hill (1992), Barabarosoglu and Yazgac (1997), Tam and Tummala (2001), Bhutta and Huq (2002), and Handfield et al. (2002). De Boer et al., (1998) who applied the quantitative criteria of price, distance, turnover and qualitative criteria of quality image to evaluate and select the supplier.

2.2.2 Total Cost of Ownership (TCO)

TCO is an estimation of overall cost which is involved with a product over its life cycle. Generally, it is always calculated at the beginning of the purchasing process to determine and compare the optimum cost effectiveness. There are many costs that are used to calculate since the cost of item until the cost which has not been incurred. Monczka and Trecha (1988), Smytka and Clemens (1993), Roodhooft and Konings

(1996), and Bhutta and Huq (2002) tried to integrate the total cost into the evaluation model. Bhutta and Huq (2002) studied the comparison between TCO and AHP for the supplier selection problem. When cost data is included as in TCO, then the AHP model has the ability to afford more efficient tools for the decision maker or can help manage to evaluate and select suppliers.

2.2.3 Mathematical Programming (MP)

The MP model is frequency used for determining the supplier selection issue in terms of the objective function to be minimized for instance minimize cost, or maximize profit by variable values in the objective function. There are several research studies applied to single objective techniques. These contain goal programming (Buffa & Jackson, 1983; Karpark, Kumcu & Kasuganti, 1999), liner programming (Pan,1989; Ghodsypour & O'Brien, 1998), or mixed integer programming (Chaudhry , Forst & Zydiak, 1993; Rosenthal, Zydiak & Chaudhry, 1995; Ghodsypour & O'Brien, 2001) to resolve the problem of supplier selection. Most of the MP model will take the price as the objective function with other criteria such as quality, delivery, capacity and so on. It takes into account constraints. However, the MP model is quite complex and is not proper for the company that desires to deal with the supplier selection problem effectively without applying advanced computer programmers. There also are two major problems with this model. Firstly, the constraint criteria are considered to weight equally which seldom happens in practice. Secondly, only quantitative criteria are usually considered (Ghodsypour & O'Brien, 1998).

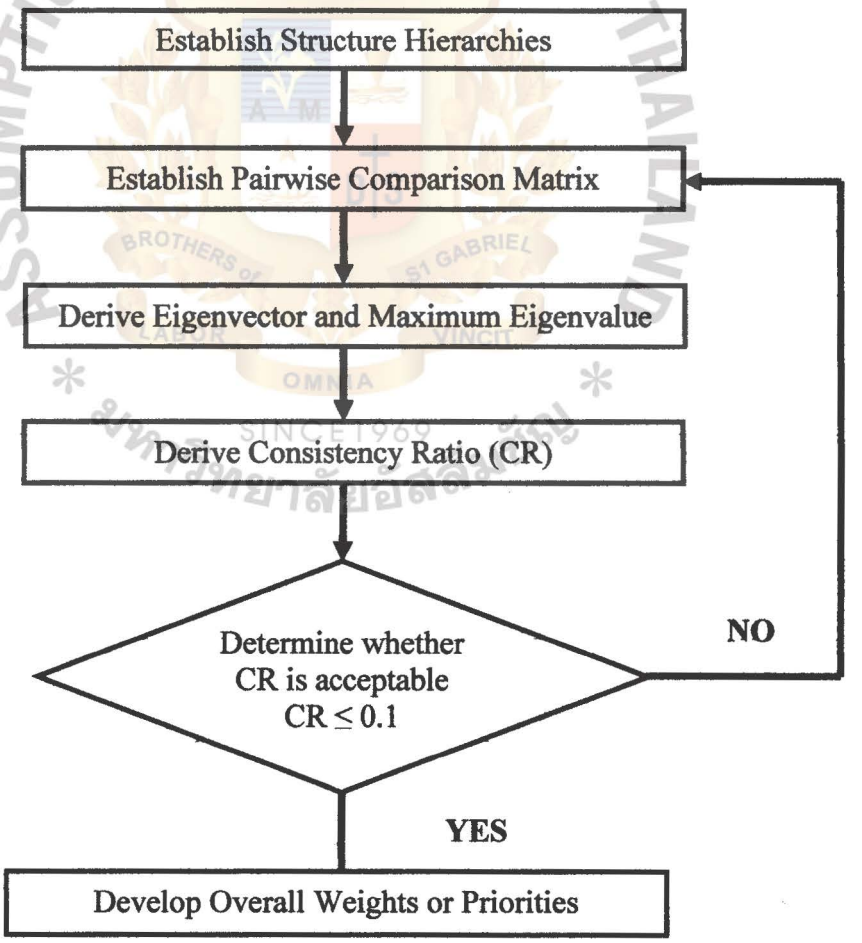
2.3 The Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process construct based from mathematics which provides a framing to cope with multi-criteria situations which involves qualitative and quantitative factors. AHP was developed by Dr.Thomas L. Saaty when he was studying at the Wharton school of business, and it was published in a book in 1980. The AHP is a decision making tool used for ranking alternatives when multi-criteria are considered. The AHP prioritizes competing factors by determining into percentage

points each factor of the decision. AHP can be applied to forecasting, budgeting and pricing decisions.

The AHP method separates a complex problem into a hierarchy of elements. Pairwise comparison is designated from each hierarchy's elements with a nominal scale. After that, comparisons are quantified to determine a comparison matrix, and then the eigenvector of the matrix is derived to signify the comparative weights among the elements of the hierarchy. Lastly, the eigenvalue will be used to evaluate the consistency ratio (CR) of the comparative matrix and determine whether the information is acceptable. The AHP process flowchart is shown in Figure 2.1.

Figure 2.1: The Analytical Hierarchy Process Flowchart

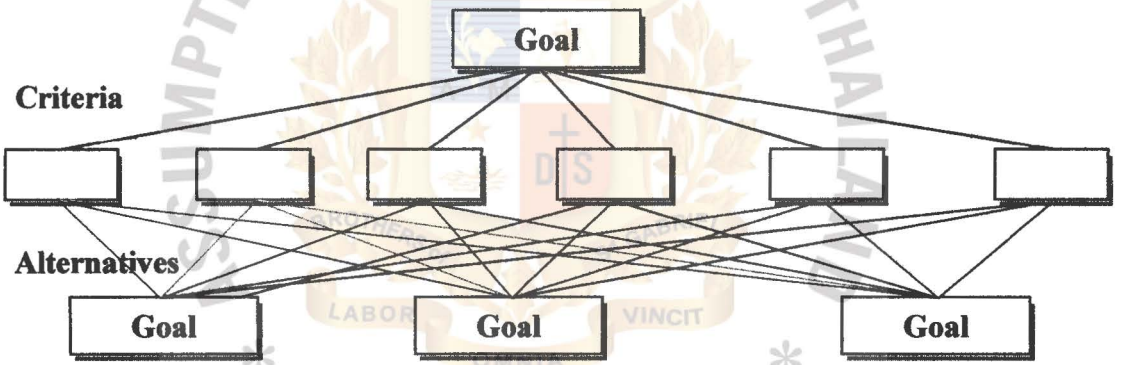


Source: Liang (2003)

2.3.1 Hierarchy

Hierarchy is a method which represents a complicated problem into a multilevel structure. Normally, the first level is the goal then followed by the levels of factors such as criteria, sub-criteria and so on down to the lowest level of alternatives. A hierarchy is also an appropriate way to distinguish an explanation for a complicated problem into a linear chain. The illustration of the three level hierarchies is shown in Figure 2.2. The intent of a hierarchy is to reach the impact of elements of a higher level on a lower level to fulfill the elements of the level above. This kind of evaluation is usually made by a pairwise comparison.

Figure 2.2: A Three Level Hierarchy



The Hierarchy requires setting priorities of measurement throughout the structure, and then synthesizing the measurements to obtain priorities for the bottom level alternatives. The most significant aspect of the AHP is use of ratio scales. They are special kinds of numbers that can be multiplied down a hierarchy and still define a resulting ratio scale. No other kind of derived scales have this property. Ratio scales and hierarchies are well suited to be together.

2.3.2 Paired Comparison

To manage with the objects, the scientists usually employ the ratio scale to measure the relationship between things. As the AHP method is making paired comparisons and derives its ratio scale from a relative number of the elements. It is conducted from

judgments on comparisons of criteria to defining importance, preference or likelihood of the considered criteria into numerical figures and then derives them into a ratio scale. Therefore, decision making with the AHP method is based on the ranking of activities of the relative ratio scales. So, the aim of pairwise comparison matrix is to derive the relative importance among the elements. The AHP used a nominal scale to reach a pairwise comparison evaluation by using the values of 1-9 to measure the different weights.

2.3.3 The Scale

The AHP pairwise comparison applies the fundamental scale of absolute numbers to compare the two criteria with respect to an attribute between large and small units. In order to determine the larger into an absolute number from the fundamental scale, it assigns two number into w_i and w_j and creates the ratio w_i/ w_j. Then assigns a number from the fundamental one to nine scale to represent the ratio $(w_i/ w_j)/1$. The determined scale showed what the w_i and w_j are. The one-nine scale of the AHP approach is a simple scale that assists well because it can make concessions between nearby numbers when greater precision is needed. The comparisons are absolute numbers shown in Table 2.3.

Table 2.3: The AHP Pairwise Comparison Valued

Intensity of Importance	***Definition***	***Explanation***
1	Equally importance	Two activities contribute
2	Equally to moderately importance	-
3	Moderately importance	Experience and judgment
4	Moderately to strongly importance	-
5	Strongly importance	Experience and judgment
6	Strongly to very strongly importance	-
7	Very strongly importance	An activity is favored very
8	Very strongly to extremely importance	-
9	Extremely importance	The evidence favoring one

Source: Render and Stair (2000)

The scale defines the level of comparative importance from equal, moderate, strong, very strong to an extreme level by numerical figures 1, 3, 5, 7 and 9 respectively. The middle value between the two comparisons is defined as numbers 2, 4, 6 and 8. The nine point scale was developed by Saaty which has been accepted by numerous experts as it is scientific and a reasonable basis of comparing between two alternatives (Taylor, 2010).

The next process is to develop a set of pairwise comparisons in order to prioritize the criteria based on a measurement scale and then put it in the matrix to compare the criteria respectively such as shown in Table 2.4. For example, cost is expected to be moderately preferred to quality, then score a number of 3 at the upper corner of the matrix. After that, use the similar scale of cost which is extremely preferred to service, from now they score a number of 9 in the row. Since the cost is very strongly preferred to technology, then they score a number of 7 in the row. In the same way to other rows can be indicated. On the opposite side of the matrix, the column 1 is scored 1/3, 1/7 and 1/9 for the comparison of quality to cost, technology to cost and service to cost respectively. For the other columns, they can fill them in in a similar manner.

Table 2.4: Criteria Matrix

Original Matrix				
	Cost	**Quality**	**Service**	**Technology**
Cost	1	3	9	7
Quality	1/3	1	5	7
Service	1/9	1/5	1	5
Technology	1/7	1/7	1/5	1

Source: Khurrum & Faizul (2002)

As soon as the pairwise comparison matrix is designated, the priorities are calculated by summing the column and row of the pairwise comparison matrix and then making the sum equal to 1. In the application of the AHP, it is able to check the consistency of judgment by calculating the consistency ratio (CR) as follows:

$$CR = \frac{CI}{RI} \qquad \text{---------Eq. (2.1)}$$

Where CI is the consistency index and RI is the random index. CI definite is calculated as:

$$CI = \frac{(\lambda \max - n)}{(n-1)} \qquad \text{---------Eq. (2.2)}$$

To calculate the consistency, the first calculation is to solve $\lambda \max$ which enables the researcher to calculate the consistency index and hence the consistency ratio.

$$\lambda \max = \frac{\text{Sum of } [A_i w_i / \text{eigenvector}_i]}{\text{Number of eigenvector}}$$

The priority vector (Aw) is from the sum of the multiplied pairwise comparison matrix (A) with the average of each row (w). After that, average the divide priority vectors to each eigenvalue to obtain the largest eigenvalue of the matrix ($\lambda \max$)

Where:

A_i = pairwise comparison matrix

w_i = the average of each row or eigenvector

CI = the sum of consistency vector

$\lambda \max$ = the largest eigenvalue of matrix

n = total number of alternatives

The principal Eigen value is obtained from the summation of products between each element of Eigen vectors and the sum of the columns of the reciprocal matrix. RI is the random index which related to the size of the matrix as shown in the Table 2.5.

Table 2.5: Random Index Values for Matrices

Size of Matrix (n)	*RI*
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

After calculations, the CR value must be lower than 10 percent or 0.1 if judgments are considered consistent (Yurdakul , 2004). On the contrary, if the CR value is more than the mentioned value, the matrix results are inconsistent and were exempted from further analysis (Wong & Li, 2007).

2.4 Potential uses for the AHP

The scales alternative technique is an advantage for the decision maker to approach an agreement quickly by applying the ranking to drive the AHP model. AHP applications can also apply to use in forecasting and budgeting. In order to improve a sale or income, forecasting plays an important role which is concerned with non-quantitative research. For example, a communication of the firm might be relevant with government regulation, population shifts, interest rates and competing technology. Using AHP to weight these kinds of elements can assist the management of the relative importance of each element. Even though the elements can be ranked without using AHP, it would not tell the relative importance between the elements from the AHP method.

The real world situation is always involved with alternatives or choices in solving problems. For instance, a budget problem may consist of determining what elements affect the budget and how much the element affects the budget. In the following, the AHP can manage multiple levels of problem by generating the weighting for the alternatives of problems then multiplying them together to find out the overall weighted score.

2.5 Why is AHP Easy to use?

Although there is difficulty with the mathematic fundamentals of the AHP, it still meets the criteria of easiness of use without prior knowledge of the theory. Here are some reasons to insist the easiness of AHP in both academic and in a level of decision making in several organizations.

i. It does not need advanced technical knowledge, so almost everyone can use it.

ii. It obtains consideration judgments based on people's emotions and feelings.

iii. It handles the tangibles side by side with intangibles which understand the senses and similar ways that people feel.

iv. It originates scales from comparisons rather than drawing numbers directly from the mind.

v. It relies on simple to complex hierarchical structures to present decision problems. As an appropriate structure, it can handle the problem of conflict, risk and prediction.

vi. It affords a simple and effective method to get an answer, even in group decision making where diverse expertise and preferences must be considered.

2.6 Summary

This chapter is summarizing the literature reviews which are relevant with the study of supplier selection criteria, supplier selection approach and the analytic hierarchy process. The literature review assists to enlighten the main concept of the research where its knowledge is useful for further chapters of the study.

CHAPTER III

RESEARCH METHODOLOGY

The ABC Company deals with several suppliers of pipelines which is the core product of the business. Three pipeline suppliers are considered for this study. To select the appropriate suppliers, the researcher needs to construct the model to approach the Analytic Hierarchy Process (AHP). The methodology was implemented from the approaches method that was mentioned in literature review.

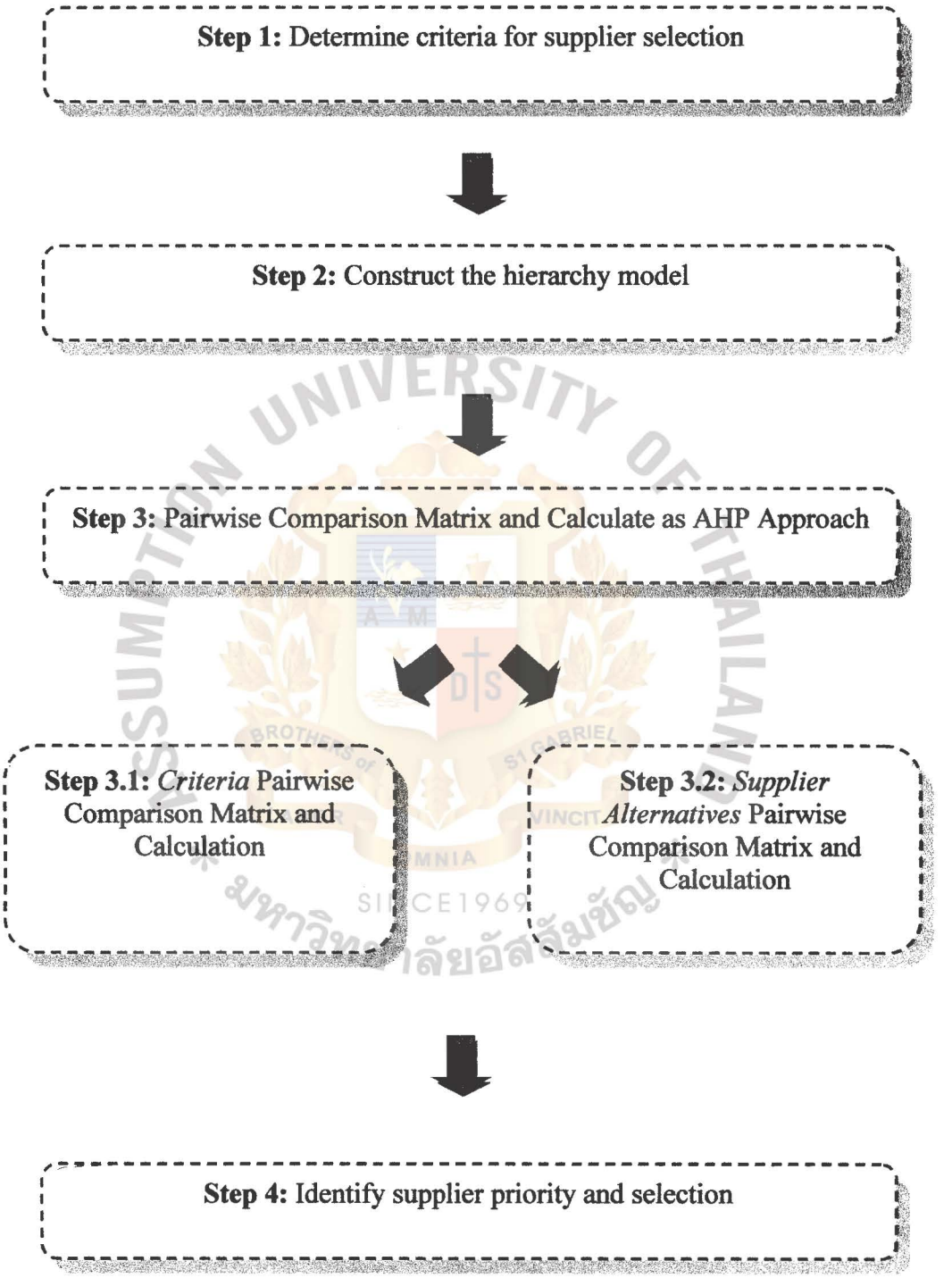
3.1 Research Design

Selecting a suitable supplier is the basis of making a company successful. This study presented the Analytical Hierarchy Process (AHP) on supplier selection for a trading company which was based on multi-criteria decisions. All criteria are weighted by three decision makers, which compose of one purchasing manager and two purchasing officers. The hierarchical structure allowed the researcher to understand the variables involved and its relationship. For this study, four criteria which are compose of price, quality, warranty and delivery are considered respectful to three alternative suppliers from China, Korea and Singapore. Then, all criteria and alternative suppliers are evaluated through a matrix pairwise comparison by three judges of ABC Company underneath quantitative and qualitative factors to select the appropriate supplier. The supplier who has the highest overall weighted score is selected as the best supplier.

3.2 Research Approach

From Figure 3.1 it shows the steps of the AHP procedure in order to select the appropriate pipeline's supplier for this study.

Figure 3.1: AHP Procedure



Source: Liang (2003)

There are four steps of AHP procedure as follows:

Step 1: Determining Criteria for Supplier Selection

The beginning step of the study is to determine the relevant criteria to find the appropriate supplier. The researcher summarizes the important criteria from the recommendation of the six research studies which is shown in Table 3.1.

Table 3.1: Criteria for Supplier Selection

Researchers	Concerned Criteria
Dickson (1966)	Delivery, Performance History, Quality, Warranty Policy
Weber et al. (1991)	Delivery, Price, Quality
Deng et al. (1995)	Delivery, Price, Quality
Ghodsypour et al.(1998)	Delivery, Quality, Service
Karpak et al. (2001)	Delivery, Price, Quality
Zhang et al.(2003)	Delivery, Price, Quality

According to Table 3.1, the most frequent criteria found in the literature are delivery, price and quality. Two out of six researches were studied in the retail, manufacturing and import industry where the business context are similar to ABC which is a trading firm that imports products i.e. pipelines from overseas. Weber et al. (1991) studied the supplier selection criteria under retail environments and manufacturing, while Deng et al. (1995) studied supplier selection criteria of the US importers. Both studies recommended the same supplier selection criteria which are delivery, price and quality.

To fit well with the actual business context, Dickson's 23 supplier selection criteria are considered. Six workers of ABC Company were asked to rank the importance of the 23 criteria. These six persons who were invited to rank these criteria have high experience and expertise in pipelines. They are now working in the purchasing department, sale manager, quality control manager and as a logistic manager. The working experiences of each informant are presented in Table 3.2 as follows:

Table 3.2: Position and Work Experience of Six Ranking Judges

Number	Position	Work Experience (year)
1	Purchasing Manager	7
2	Purchasing staff	3
3	Purchasing staff	1
4	Sale Manager	2
5	Quality Control Manager	5
6	Logistic Manager	5

The ranking results are computed based on the individual ranking score. The individual ranking scores were weighted with the rank number. The weighted scores of each individual judge were multiply with the frequency and then summed to gain the total weighted scores. The results are shown as the Table 3.3.

Table 3.3: Criteria for Supplier Selection Ranking by ABC Company

Criteria	Total Weight Score	Rank
Price	**10**	**1**
Quality	**12**	**2**
Delivery	**14**	**3**
Warranty Policy	**38**	**4**
Production Facilities and Capacity	43	5
Technical Capability	64	6
Communication System	66	7
Impression	69	8
Repair Service	72	9
Reputation and Position in Industry	73	10
Performance History	75	11
Financial Position	76	12
Attitude	77	13
Procedural Compliance	81	14
Geographical and Location	85	15
Management and Organization	86	16
Amount of Past Business	89	17
Packing Ability	90	18
Operating Controls	92	19
Desire for Business	93	20
Training aids	111	21
Labor Relations Record	115	22
Reciprocal Agreement	125	23

The first four ranks which are price, quality, delivery and warranty are suggested by the ranking information. These four criteria are consistent with the first four supplier selection criteria recommended by the previous literature. As such, these four criteria are focused on in this study.

After the appropriate criteria are specified, there is in depth discussion in detail with the decision makers who have responsibility to select the appropriate supplier. The researcher set up the meeting and invited decision makers of the ABC Company to discuss and share ideas about the important criteria using for supplier selection. All decision makers agreed that only price was concerned in supplier selection as insufficient as the exist practice that the company can lose around 4 million Thai Baht a year for a pipeline rejection. Therefore, the decision makers made the consensus to select the influencing criteria under the collaboration study in order to select the greatest supplier based on the AHP methodology. All decision makers agreed to select only the four ranked criteria which are price, quality, delivery and warranty which was supported by Weber et al. (1991), Deng et al. (1995), Karpak et al. (2001) and Zhang et al.(2003). So, there are four criteria used in the supplier selection study of ABC Company. The explanations of criteria are hereinafter:

a. Price

This considered criterion includes the credit terms, total price of the product and transportation costs of each overseas supplier. The lower offered total price is always preferable because it related with the margin of the company.

b. Quality

A quality criterion includes supplier's certification, technical techniques and quality of raw material. All pipelines will be inspected by the quality control department when they arrive at the warehouse. QC staff checked the quality of the pipeline in terms of the wall thickness and general external conditions such as dents and cracks.

c. Delivery

Since the suppliers supply the pipeline from overseas, the lead time is considered in order to deliver to the client on time. Suppliers who offer shorter lead-times are also preferable because it is a benefit to both clients and the company.

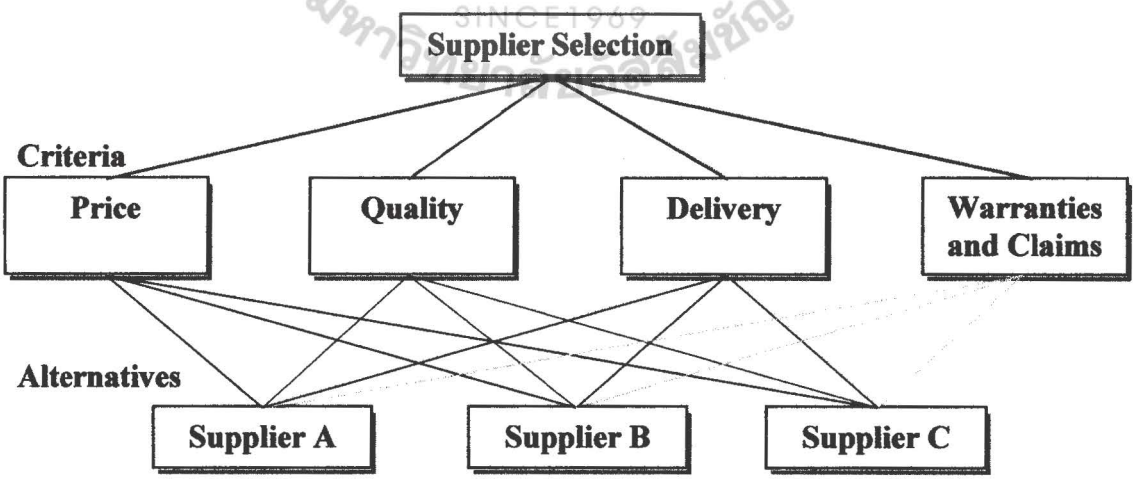
d. Warranty

As the pipeline is a high value product, the warranty and claim is also important criteria which should be considered. The suppliers who offer the warranties and claims when the products are damaged is preferable to consider and select.

Step 2: Construct the Hierarchy Model

After setting up the criteria, this step involves constructing the problem into a hierarchy in order to see the entire perspective. The developed AHP hierarchy model is based on the determined four criteria and three alternative suppliers as shown in Figure 3.2.

Figure 3.2: AHP Hierarchical Level of Decision Making for Supplier Selection



The goal of the analysis is to select the suppliers in level one. Level two is a multi-criteria set up which consists of several criteria that are relevant to the Company's context and situation. Then, the last level is the alternative choices.

Step 3: Pairwise Comparison Matrix and Calculation

The pairwise comparison is the process of comparing entities in pairs in order to judge and find the relative importance of each entity which is preferred. For this study, four criteria and three alternative suppliers are pairwise reciprocally in supplier evaluation form by three decision makers. The comparison weighted by the nine point scale proposed by Saaty (1980) is shown in Table 3.4.

Table 3.4: Pairwise Comparison Values between Two Elements

Verbal Judgment or Preference	Numerical Judgment
Extremely Preferred	9
Very Strongly to Extremely	8
Very Strongly Preferred	7
Strongly to Very Strongly	6
Strongly Preferred	5
Moderately to Strongly	4
Moderately Preferred	3
Equally to Moderately	2
Equally Preferred	1

Source: Saaty (1980)

From Table 3.4, the level of relative importance is indicated from equal, moderate, strong, very strong to extreme levels by numbers 1, 3, 5, 7 and 9 respectively. Besides, the intermediate value between two adjacent factors is presented by 2, 4, 6 and 8 respectively.

After the decision makers weighted all criteria and alternatives in the supplier evaluation form, then the researcher brings each pairwise score to be filled in the table as the matrix by separating them into two major groups which are pairwise of criteria and pairwise of alternative suppliers which are explained in the calculation step of each pairwise in step 3.1 and 3.2 successively.

Step 3.1: Criteria Pairwise Comparison Matrix

This step is to fill in the pairwise score which was weighted by the decision makers from the supplier evaluation form in the matrix table. Four criteria composed of price, quality, delivery and warranty are determined in this study.

Table 3.5 Criteria Pairwise Comparison Matrix

Criteria for Supplier	Price	Quality	Delivery	Warranty
Price	1			
Quality		1		
Delivery			1	
Warranty				1

Referring to Table 3.5, the matrices are developed wherein each criteria is compared against others to prioritize the criteria. Suppose price criterion is moderately preferred over quality. According to the scale above, the value of 3 denotes the preference of this pairwise comparison. Then, quality criterion is denoted with a valued of 1/3 compared to price. In the same way, if the decision maker decides that warranty criterion is strongly non-preferred over price, the valued of 1/5 is denoted according to the scale table above. Also the price criterion is denoted with a value of 5 as reciprocal value over the warranty criterion. Therefore, the comparative of each criteria of itself against others will be the opposite relationship of the score given. Moreover, the value of 1 is always the comparison value of itself which is placed down diagonal from the upper left corner to the lower right corner.

Step 3.2: Alternative Suppliers Pairwise Comparison Matrix

This part is still compared between two elements by filling in the score from the supplier evaluation form which was weighted by the decision makers into matrix table in step 3.1. However, it changes from criteria pairwise to alternative suppliers pairwise per each criterion. For this study, there are three suppliers which are supplier A from China, supplier B from Korea and supplier C from Singapore. So in this part,

there are four matrix tables to be constructed in order to have pairwise reciprocal suppliers with four criteria.

Towards this end of the pairwise matrix comparison table, if the judgment value is in above or on the right hand side of 1 then put the actual judgment value, if the judgment value is below or on the left hand side of 1 then put the reciprocal value.

After obtaining the pairwise judgment of the criteria and the alternative suppliers in step 3.1 and 3.2, the next step is to calculate the weighted score in the matrix table in order to determine the priorities of supplier selection. The calculation process can be summarized in five steps:

i. Sum the value in each column of the pairwise comparison matrices.

ii. Divide each value in each column of the pairwise comparison matrices by the proportion of the column sum. The results show the normalized matrices.

iii. Average the weighted score in each row of the normalized matrix. The results of this calculation present the preference vectors. From the normalized table which sums all elements is converted into one, and then the researcher can identify the priority vector from the average value of each criterion. The priority vector or eigenvector shows relative weights among the compared elements.

iv. This step is to calculate the eigenvalue and eigenvector. Pairwise comparison matrix (A) as normalized in step 3.1 and 3.2, while eigenvector (w) is obtained from the average of each row. In order to obtain the local priority vector (Aw), this step is to sum the multiplied eigenvector with matrix A. Then, divide Aw by the eigenvector value for every criterion or supplier. The average of these results shows the largest eigenvalue of the matrix (λ max).

Calculate the average values to obtain λ max;

$$\lambda \max = \frac{\text{Sum of } [A_i w_i / \text{ eigenvector}_i]}{\text{Number of eigenvector}}$$

v. The last step of calculation is to implement the consistency test. After calculating all the pairwise comparisons, the consistency is assigned by using the eigenvalue ($\lambda \max$) to calculate the consistency index (CI).

Calculate the Consistency Index (CI) is found by;

$$CI = \frac{(\lambda \max - n)}{(n-1)} \qquad \text{---------Eq. (3.1)}$$

Where n = the number of compared items

The next step is to calculate a Consistency Ratio (CR) in order to measure the consistent judgment. The consistency test is an important step for the AHP method because it purposes to get rid of the possible inconsistency revealed in the criteria weighted through the calculation of each matrix consistency level.

$$CR = \frac{CI}{RI} \qquad \text{---------Eq. (3.2)}$$

The value of RI is selected from the table 3.6

Table 3.6: Random Index Values for Matrices

Size of Matrix (n)	*RI*
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Regarding to Saaty (1980), an acceptable pairwise comparison is weighted reasonably consistent when CR = 0.10. However, if the CR value is lower than 0.1, then the weighted results are consistent (Al-Harbi, 2001). On the contrary, if the CR value is more than the acceptable value then the matrix results are invalid or inconsistent. So it will be rejected for further analysis and the decision maker should reexamine the pairwise comparison in order to get in the acceptable range.

Step 4: Identify Supplier Priority and Selection

In order to identify the optimal supplier, the overall score of each supplier is compared and the highest overall ranking is recognized as the appropriate supplier. The overall score of each supplier is calculated by the sum of all multiplying priority vectors of each criterion with priority vectors of suppliers with respect to the criterion.

Once one supplier is approved as the appropriate supplier, the company must reevaluate on a periodic or quarterly basis with the same criteria in order to ensure that the supplier still maintains an acceptable standard. The AHP approach is an executable and proficient solution for the company who finds the appropriate supplier without visiting overseas manufacturing which saves the company money. With the use of AHP in supplier selection, it benefits the Company not only to get competitive prices but also to provide punctual delivery, good quality and an advantage of warranty offered. In applying this method with the business, it has a tendency to reduce losing costs when compared with the existing method which is concerned only with the lowest price. The loss of the Company normally occurred in 2012 and 2013 averaged THB 4 Million. The company can take advantage of this supplier selection method by reducing the lost cost from four concerned criteria. Firstly, the company gets the products at a competitive price which affects directly to profit margins. Secondly, in terms of submitting the pipeline to customers' on-time the company does not have to pay the penalty fee for 0.2% of the purchase order amount. Thirdly, if the pipelines arrive at the warehouse in perfect quality condition then the QC staff does not need repair or the Company does not have to pay overtime for them. Lastly, the company has less risk when one supplier offers the warranty because the Company

can ensure that unexpected burden cost is paid by the supplier. From the rationale mentioned, AHP must assist the Company to reduce losing costs more than 50% or around THB 2 Million a year. Moreover, there are still some uncontrollable factors such as late delivery from natural disasters or port congestion and the pipeline damage while delivering which aforementioned are not the supplier's mistake.

3.3 Summary

This chapter explains the methodology of steps used to fulfill the objective of this study. The researcher applies multi decision making tools called Analytical Hierarchy Process (AHP) to evaluate and select the optimal supplier. Initially, the influential criteria to this study are determined which were composed of delivery, quality, price and warranty policy. Then, the hierarchy model is constructed in order to evaluate and weight scores by three persons from purchasing department of ABC Company. The judgment data are calculated based on the AHP approach which was created in a spreadsheet program of Microsoft Excel. Lastly, the overall weighted score for each decision of alternatives are shown and then the researcher was able to select the best supplier from the highest overall weighted score.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

This chapter presents the data collection, data analysis and the discussion of the results. In order to evaluate and select the appropriate pipeline supplier for ABC Company, four criteria (price, quality, delivery and warranty) and three alternative suppliers (supplier A, B and C) are evaluated by the AHP approach. All criteria and alternative suppliers are analyzed by pairwise comparison from three decision makers whose expertise is in commercial pipeline area of the company. From this analysis, the company will recognize multi-factors rather than a single factor, and identify for the most potential supplier.

4.1 Collected Data

The data were collected from the three decision makers and the supplier evaluation was done. The three decision makers who are currently responsible for the purchasing function were asked to compare the factors on left hand side against the factors on the right hand side, and then weight the important criteria and performance of each supplier with a numerical nine point scale.

After the three decision makers completed filling out the supplier evaluation form, pairwise comparison data and alternative suppliers' pairwise comparison data was recorded and used in the data analysis. The detailed data are shown in the following section:

4.1.1 Pairwise Comparison of the Supplier Selection Criteria

The following are the data of criteria of the pairwise comparison. The three decision makers were asked to rate the score on each criterion in the supplier evaluation form. The criteria were compared by price, quality, delivery and warranty.

Table 4.1: Pair Comparisons of the Importance of Each Criterion

Comparing Criteria			Comparative Scores		
			Decision Maker1	Decision Maker2	Decision Maker3
Price	VS	Quality	2	1	1
Price	VS	Delivery	4	5	4
Price	VS	Warranty	5	7	5
Quality	VS	Delivery	3	3	1
Quality	VS	Warranty	4	7	7
Delivery	VS	Warranty	3	4	3

Note: Less important of the first criterion is varying from -2 to -9;
More important of the first criterion is varying from 2 to 9
Equal weight =1

From the supplier evaluation form, decision maker 1 weighted price equally to moderately important to quality and hence gave it a rating of 2, whereas the decision makers 2 and 3 have a consensus that price was equally important to quality with a score of 1.

The price was rated over delivery criterion as moderately to strongly important (rated of 4) in the opinion of the decision makers 1 and 3, while it was strongly important (rated of 5) from decision maker 2.

Besides, the price was also rated over warranty criterion as strongly important (rated of 5) from decision makers 1 and 3, and it was very strongly important (rated of 7) from decision maker 2.

In terms of quality against delivery criterion, decision makers 1 and 2 have agreed that the quality was moderately important to the delivery, so they were rated 3. Even so, in the opinion of decision maker 3, the quality was equally important to delivery as it was rated a 1.

In addition to the quality criterion, it was rated a 4 over warranty criterion as moderately to strongly important from decision maker 1, nevertheless the quality rated of 7 as moderately to strongly important from decision makers 2 and 3.

Lastly, the delivery against warranty was moderately important which was rated a 3 from decision makers 1 and 3, while it was rated a 4 as moderately to strongly important from decision maker 2.

4.1.2 Alternative Suppliers Pairwise Comparison

This part of the data collection is also collected through the evaluation form which was rated by three decision makers. In this section, the decision makers have to make a judgment of the performance supplier with respect to each criterion. There were three suppliers of supplier A from China, supplier B from Korea and supplier C from Singapore that have been compared against each other using four criteria of price, quality, delivery and warranty.

Table 4.2: Comparing the Performance of Suppliers with Respect to Criterion

Criteria/Supplier	**Alternative Weight Score**		
Price Criterion	Decision Maker 1	Decision Maker 2	Decision Maker3
Supplier A VS Supplier B	3	7	4
Supplier A VS Supplier C	5	9	7
Supplier B VS Supplier C	3	3	2
Quality Criterion			
Supplier A VS Supplier B	-3	-5	-7
Supplier A VS Supplier C	-5	-6	-9
Supplier B VS Supplier C	-2	-3	-3
Delivery Criterion			
Supplier A VS Supplier B	-4	-5	-5
Supplier A VS Supplier C	-5	-4	-5
Supplier B VS Supplier C	1	1	-2
Warranty Criterion			
Supplier A VS Supplier B	-2	-2	-2
Supplier A VS Supplier C	-7	-7	-5
Supplier B VS Supplier C	-5	-6	-4

Remarks: The rating scores are gathered from the three decision makers
Less important of the first supplier is varying from -2 to -9;
More important of the first supplier varying from 2 to 9
Equal weight =1

From pairwise comparison of alternative suppliers in each criterion of decision maker 1, the score has been shown as above. In terms of price criterion, supplier A was more moderately performance and more strongly performance which were rated of 3 and 5 over supplier B and C whereas supplier B was more moderately performance rated of 3 over supplier C.

The quality criterion, performance of supplier A was less than supplier B and C which were less moderately performance and less strongly performance rated of 3 and 5, while Supplier B was less equally to moderately performance than supplier C as scored a 2.

The delivery criterion, supplier A was rated as less performance than supplier B and C as less moderately to strongly performance and less strongly performance with a rating of 4 and 5 respectively. However, supplier B and C was rated a 1 as no different or equal in performance.

Lastly for warranty criterion, supplier A performed less performance than supplier B and C which were less equally to moderately performance and less very strongly performance with a rating of 2 and 7, while supplier B was also less performance than supplier C with a less strongly performance score of 5.

For the price criterion perspective of decision maker 2, supplier A performed better in performance than supplier B and C with a rating of 7 and 9. Supplier B also performed better in performance than supplier A with a rating of 3.

The quality criterion, supplier A supplied a lower quality product than supplier B and C with a rating of 5 and 6, while supplier B also supplied lower quality products than supplier C with a score rating of 3.

In terms of delivery criterion, supplier A has less performance than supplier B and C with a rating of 5 and 4, however supplier B was equal in performance to supplier C with a rating of 1.

Lastly for warranty criterion, supplier A offered a satisfactory warranty less performance than supplier B and C with a rating of 2 and 7. And supplier A also offered a warranty less performance than supplier C with a rating of 6.

The weighting comparison in perspective of decision maker 3, supplier A offered more competitive prices than supplier B and C with ratings of 4 and 7, while supplier B offered better prices than supplier C at a rating of 2.

For quality criterion, supplier A supplied with less quality than supplier B and C at a rating of 7 and 9, and supplier B also supplied at a lower quality than supplier C with a rating of 3.

The delivery criterion, supplier A was strongly less performance when compared with supplier B and C and equally rated at 5. Supplier B was also less performance in delivery with a rating of 2 to supplier C.

Lastly, comparing each supplier with warranty criterion, supplier A performed less performance than supplier B and C with a rating of 2 and 5, while supplier B also performed less performance when compared with supplier C with a rating of 4.

4.2 Data Analyses

Microsoft Excel was used to analyze the data because it is the basic software that any company or anyone can use. The data can be easily input in the software for computation and the accurate results can be transferred to a spreadsheet for analysis (Asamoah, Annan & Nyarko, 2012). This approach makes it easier for purchasing and other supply chain staff to evaluate and select the appropriate suppliers for the company. The analyses are categorized into three parts; 1) Criteria pairwise comparison matrix, 2) Alternative suppliers pairwise comparison matrix, and 3) Overall ranking of suppliers. The details are discussed in the following sections.

4.2.1 Criteria Pairwise Comparison Matrix

Referring to the Table 4.1, the weighted score gathered from the decision makers were put in the matrix table for further calculation. The first pair wise comparison matrix shows the raw scores then the second shows the proportion that was calculated based on those scores as seen in Table 4.3 and 4.4.

Table 4.3: Pairwise Comparison Matrix with Respect to the Selected Criteria

Decision maker 1				
Criteria	Price	Quality	Delivery	Warranty
Price	1	2	4	5
Quality	1/2	1	3	4
Delivery	1/4	1/3	1	3
Warranty	1/5	1/4	1/3	1
Decision maker 2				
Criteria	Price	Quality	Delivery	Warranty
Price	1	1	5	7
Quality	1	1	3	7
Delivery	1/5	1/3	1	4
Warranty	1/7	1/7	¼	1
Decision maker 3				
Criteria	Price	Quality	Delivery	Warranty
Price	1	1	4	5
Quality	1	1	1	7
Delivery	1/4	1	1	3
Warranty	1/5	1/7	1/3	1

From the criteria pairwise comparison in Table 4.1, the pair wise score is rated as 1 when a criterion was compared to the same criterion itself. For the decision maker 1, price was weighted equally to moderately higher in importance than quality, so it was rated as a 2 in the matrix table of price against quality. Consequently, quality is 1/2 as importance to price. These numbers were then put in the matrix table of quality against price. The same procedures were done for the data gathered from the decision maker 2 and 3.

The next step, the data were analyzed by converting the fraction numbers into decimal numbers in order for calculation purposes in the further stages. After converting, all numbers in each column they were summed to prepared for the next calculation steps as shown in Table 4.4.

Table 4.4: Pairwise Comparison Matrix of the Selected Criteria and the Summate Scores

Decision maker 1				
Criteria	Price	Quality	Delivery	Warranty
Price	1.0000	2.0000	4.0000	5.0000
Quality	0.5000	1.0000	3.0000	4.0000
Delivery	0.2500	0.3333	1.0000	3.0000
Warranty	0.2000	0.2500	0.3333	1.0000
TOTAL	1.9500	3.5833	8.3333	13.0000
Decision maker 2				
Criteria	Price	Quality	Delivery	Warranty
Price	1.0000	1.0000	5.0000	7.0000
Quality	1.0000	1.0000	3.0000	7.0000
Delivery	0.2000	0.3333	1.0000	4.0000
Warranty	0.1429	0.1429	0.2500	1.0000
TOTAL	2.3429	2.4762	9.2500	19.0000
Decision maker 3				
Criteria	Price	Quality	Delivery	Warranty
Price	1.0000	1.0000	4.0000	5.0000
Quality	1.0000	1.0000	1.0000	7.0000
Delivery	0.2500	1.0000	1.0000	3.0000
Warranty	0.2000	0.1429	0.3333	1.0000
TOTAL	2.4500	3.1429	6.3333	16.0000

Then, all numbers were normalized and reverted to the proportion. So the new column sum would be equal to 1. The priority vector can be identified from the row average as seen in Table 4.5.

Table 4.5: Pairwise Comparison Matrix of the Normalized Scores

Decision maker 1					
Criteria	Price	Quality	Delivery	Warranty	**Row Average**
Price	0.5128	0.5581	0.4800	0.3846	0.4839
Quality	0.2564	0.2791	0.3600	0.3077	0.3008
Delivery	0.1282	0.0930	0.1200	0.2308	0.1430
Warranty	0.1026	0.0698	0.0400	0.0769	0.0723
TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000
Decision maker 2					
Criteria	Price	Quality	Delivery	Warranty	**Row Average**
Price	0.4268	0.4038	0.5405	0.3684	0.4349
Quality	0.4268	0.4038	0.3243	0.3684	0.3808
Delivery	0.0854	0.1346	0.1081	0.2105	0.1347
Warranty	0.0610	0.0577	0.0270	0.0526	0.0496
TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000
Decision maker 3					
Criteria	Price	Quality	Delivery	Warranty	**Row Average**
Price	0.4082	0.3182	0.6316	0.3125	0.4176
Quality	0.4082	0.3182	0.1579	0.4375	0.3305
Delivery	0.1020	0.3182	0.1579	0.1875	0.1914
Warranty	0.0816	0.0455	0.0526	0.0625	0.0606
TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000

From Table 4.5, the priority vector result of each decision makers have shown in row average column can be written as the vector as below.

Figure 4.1: Priority Vector of the Selected Criteria

	Decision maker 1	*Decision maker 2*	*Decision maker 3*
Price	0.4839	0.4349	0.4176
Quality	0.3008	0.3808	0.3305
Delivery	0.1403	0.1347	0.1914
Warranty	0.0723	0.0496	0.0606

According to Figure 4.1, decision makers 1, 2 and 3 weighted the price as the most important criteria with a score of 0.4839, 0.4349 and 0.4176, followed by quality in the second place with the scores of 0.3008, 0.3808 and 0.3305, and then the delivery criterion with the scores of 0.1403, 0.1347 and 0.1914, and lastly with warranty which had marginal scores of 0.0723, 0.0496 and 0.0606 as the least importance criteria.

To ensure the quality of the analysis results, the consistency check was performed. Once the pairwise comparisons are weighted by the three decision makers and the priority vector was obtained, the next step was to calculate the consistency ratio in order to measure the consistency of the above judgment. AHP provides the method to measure the consistency of pairwise judgments. If the consistency ratio appears in the acceptable range it is equal or less than 0.1, then it can carry on further. But, if the consistency ratio appears with a value greater than 0.1, it means the results are not consistent, then the decision maker should re-weight the pairwise comparison. The computation of the consistency can be completed by the following steps:

Step 1: Sum of the multiply priority vector with pairwise comparison matric in each column to get the weighted sum

Figure 4.2: Calculating of Weighted Sum

Decision maker 1

	Price		Quality		Delivery		Warranty		Weighted Sum
Price		1		2		4		5	2.0190
Quality	0.4839	1/2	+ 0.3008	1	+ 0.1430	3	+ 0.0723	4	= 1.2610
Delivery		1/4		1/3		1		3	0.5811
Warranty		1/5		1/4		1/3		1	0.2919

Step 2: Dividing the element of the vector of weighted sum matric by respective priority;

$$\left(\frac{2.0190}{0.4838}\right) = 4.1732$$

$$\left(\frac{1.2610}{0.3008}\right) = 4.1921$$

$$\left(\frac{0.5811}{0.1430}\right) = 4.0636$$

$$\left(\frac{0.2919}{0.0723}\right) = 4.0373$$

Step 3: Calculate the average values to obtain λ max;

$$\lambda \max = \frac{4.1732+4.1921+4.0636+4.0373}{4} = 4.1165$$

Step 4: Calculate the Consistency Index (CI) is found by;

$$CI = \frac{(\lambda \max - n)}{(n-1)} \qquad \text{---------Eq. (4.1)}$$

Where n = the number of compared items

$$CI = \frac{(4.1165 - 4)}{(4-1)} = 0.0389$$

Select the Random Index (RI) from the numbers as developed by Saaty (1980)

Size of Matrix (n)	*RI*
1	0
2	0
3	0.58
4	**0.9**
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Due to the size of matric is four (price, quality, delivery, and warranty), so the value of RI equal to 0.9.

Step 5: Calculate the Consistency Ratio (CR) is defined as;

$$CR = \frac{CI}{RI} \qquad \text{---------Eq. (4.2)}$$

$$CR = \frac{0.0389}{0.9} = 0.0432$$

As the value of CR is less than 0.1, the judgments are acceptable (Al-Harbi, 2001). The above matrix multiplication function **(MMULT)** was performed to analyze the consistency of decision maker 1, 2 and 3. The results are shown in Table 4.6 below

Table 4.6: Consistency Analysis of Decision Maker 1

	A	B	C	D	E	F	G	H	I	J	K	L			
	Criteria	Price	Quality	Delivery	Warranty		Price	Quality	Delivery	Warranty	Row Average	Consistency Measure	CI	RI	CR
1	Price	1	2	4	5		0.5128	0.5581	0.4800	0.3846	0.4839	4.1732	0.0389	0.9000	0.0432
2	Quality	1/2	1	3	4		0.2564	0.2791	0.3600	0.3077	0.3008	4.1921			
3	Delivery	1/4	1/3	1	3		0.1282	0.0930	0.1200	0.2308	0.1430	4.0633			
4	Warranty	1/5	1/4	1/3	1		0.1026	0.0698	0.0400	0.0769	0.0723	4.0373			
					TOTAL		1.0000	1.0000	1.0000	1.0000	1.0000	-			
							0.5128	0.5581	0.4800	0.3846	0.4839	4.1732	0.0356	0.9000	0.0395
							0.2564	0.2791	0.3600	0.3077	0.3008	4.1921			
							0.1282	0.0930	0.1200	0.2308	0.1430	4.0633			
							0.1026	0.0698	0.0400	0.0769	0.0723	4.0373			
					TOTAL		1.0000	1.0000	1.0000	1.0000	1.0000	-			
							0.5128	0.5581	0.4800	0.3846	0.4839	4.1732	0.0757	0.9000	0.0841
							0.2564	0.2791	0.3600	0.3077	0.3008	4.1921			
							0.1282	0.0930	0.1200	0.2308	0.1430	4.0633			
							0.1026	0.0698	0.0400	0.0769	0.0723	4.0373			
					TOTAL		1.0000	1.0000	1.0000	1.0000	1.0000	-			

The consistency measures were computed based on the MMULT technique. Consistency of price was calculated by: MMULT = (B1:E1, K1:K4)/K1; quality: MMULT = (B2:E2, K1:K4)/K2; delivery: MMULT = (B3:E3, K1:K4)/K3 and warranty; MMULT = (B4:E4, K1:K4)/K4. Both calculation methods appeared exactly the same and were accurate results. So the researcher selected to take advantage of this software for further calculation analysis.

From the consistency ratio result of all decision makers the scores are 0.0432, 0.0395 and 0.0841 respectively. They are all less than 0.1 which shows consistency. The consistency ratio (C.R.) is calculated to check the acceptance of the priority weighting. Satty (1980) suggested that a C.R. equal to or less than 0.1 is acceptable.

Therefore, the above analyses of criteria are consistent and the priority vectors are summarized in Figure 4.3.

Figure 4.3: The Average Priority Vector Categorizes by Criterion

	Decision maker 1	*Decision maker 2*	*Decision maker 3*	*Average Score*
Price	0.4839	0.4349	0.4176	0.4455
Quality	0.3008	0.3808	0.3305	0.3374
Delivery	0.1403	0.1347	0.1914	0.1564
Warranty	0.0723	0.0496	0.0606	0.0608

When interpreting the results of the average vector, it can summarize that the priority of each criterion to price, quality, delivery and warranty had scores of 0.4455, 0.3374, 0.1564 and 0.0608 respectively.

4.2.2 Alternative Suppliers Pairwise Comparison Matrix

This analysis process is similar to that of the criteria pairwise comparison matrix in topic 4.2.1, but all suppliers A, B and C respective to each criterion of price, quality, delivery and warranty were computed and the results were put in the same matrix as:

A. Price

Table 4.7: Consistency Analysis of the Price Criterion

	Decision Maker 1							
Price	Supplier A	Supplier B	Supplier C	Row Average	Consistency Measure	CI	RI	CR
Supplier A	0.6522	0.6923	0.5556	0.6334	3.0717	0.0194	0.5800	0.0334
Supplier B	0.2174	0.2308	0.3333	0.2605	3.0327			
Supplier C	0.1304	0.0769	0.1111	0.1061	3.0117			
TOTAL	1.0000	1.0000	1.0000	1.0000				
	Decision Maker 2							
Supplier A	0.7975	0.8400	0.6923	0.7766	3.1901	0.0411	0.5800	0.0708
Supplier B	0.1139	0.1200	0.2308	0.1549	3.0429			
Supplier C	0.0886	0.0400	0.0769	0.0685	3.0135			
TOTAL	1.0000	1.0000	1.0000	1.0000				
	Decision Maker 3							
Supplier A	0.7179	0.7273	0.7000	0.7151	3.0043	0.0010	0.5800	0.0017
Supplier B	0.1795	0.1818	0.2000	0.1871	3.0012			
Supplier C	0.1026	0.0909	0.1000	0.0978	3.0004			
TOTAL	1.0000	1.0000	1.0000	1.0000				

From Table 4.7, the row average identified priority vectors which were weighted by decision makers. Decision makers 1, 2 and 3 were weighted in the same sequence and the best performance respective of price criterion is supplier A with scores of 0.6334, 0.7766 and 0.7151, followed by supplier B with scores of 0.2605, 0.1549 and 0.1871, and the lease performance in price criterion is supplier C which scores are 0.1061, 0.0685 and 0.0978 respectively.

The consistency ratio of the price criterion of decision maker 1, 2 and 3 are 0.0334, 0.0708 and 0.0017 respectively, which are in the acceptable range of consistency data that is lower than 0.1. So the priority vector value can be used for the next process.

Figure 4.4: The Average Priority Vector of the Price Criterion

PRICE	***Decision maker 1***	***Decision maker 2***	***Decision maker 3***	***Average Score***
Supplier A	0.6334	0.7766	0.7151	0.7084
Supplier B	0.2605	0.1549	0.1871	0.2008
Supplier C	0.1061	0.0685	0.0978	0.0908

From the summary of priority vectors in figure 4.4, the average weighting of the three decision makers showed that supplier A is the best performance of price as the average priority is 0.7084, follow by supplier B and C which have a priority of 0.2008 and 0.0908 respectively.

B. Quality

Table 4.8: Consistency Analysis of Quality Criterion

	Decision Maker 1							
Quality	Supplier A	Supplier B	Supplier C	Row Average	Consistency Measure	CI	RI	CR
Supplier A	0.1111	0.1000	0.1176	0.1096	3.0015	0.0018	0.5800	0.0032
Supplier B	0.3333	0.3000	0.2941	0.3091	3.0035			
Supplier C	0.5556	0.6000	0.5882	0.5813	3.0061			
TOTAL	1.0000	1.0000	1.0000	1.0000				
	Decision Maker 2							
Supplier A	0.0833	0.0476	0.1111	0.0807	3.0202	0.0476	0.5800	0.0820
Supplier B	0.4167	0.2381	0.2222	0.2923	3.0946			
Supplier C	0.5000	0.7143	0.6667	0.6270	3.1707			
TOTAL	1.0000	1.0000	1.0000	1.0000				
	Decision Maker 3							
Supplier A	0.0588	0.0345	0.0769	0.0567	3.0123	0.0407	0.5800	0.0701
Supplier B	0.4118	0.2414	0.2308	0.2947	3.0814			
Supplier C	0.5294	0.7241	0.6923	0.6486	3.1502			
TOTAL	1.0000	1.0000	1.0000	1.0000				

From Table 4.8, decision maker 1, 2 and 3 have a consensus that supplier C is the best supplier who supplied good quality material with scores of 0.5813, 0.6270 and 0.6486, followed by supplier B with scores of 0.3091, 0.2923 and 0.2947, and the lowest in quality supplied is Supplier A with scores of 0.1096, 0.0807 and 0.0567.

Moreover, the consistency ratio of the quality criterion of decision maker 1, 2 and 3 are 0.0032, 0.0820 and 0.0701 respectively, and all values are acceptable.

Figure 4.5: The Average Priority Vector of the Quality Criterion

QUALITY	*Decision maker 1*	*Decision maker 2*	*Decision maker 3*	*Average Score*
Supplier A	0.1096	0.0807	0.0567	0.0823
Supplier B	0.3091	0.2923	0.2947	0.2987
Supplier C	0.5813	0.6270	0.6486	0.6190

In terms of the quality criterion, supplier C is the best performance on supplied quality products to ABC Company with the highest average score of 0.6190, followed by supplier B with the average score of 0.2987 and supplier A who obtained the lowest score at 0.0823.

C. Delivery

Table 4.9: Consistency Analysis of Delivery Criterion

	Decision Maker 1							
Delivery	Supplier A	Supplier B	Supplier C	Row Average	Consistency Measure	CI	RI	CR
Supplier A	0.1000	0.1111	0.0909	0.1007	3.0017	0.0028	0.5800	0.0048
Supplier B	0.4000	0.4444	0.4545	0.4330	3.0070			
Supplier C	0.5000	0.4444	0.4545	0.4663	3.0079			
TOTAL	1.0000	1.0000	1.0000	1.0000				
	Decision Maker 2							
Supplier A	0.1000	0.0909	0.1111	0.1007	3.0017	0.0028	0.5800	0.0048
Supplier B	0.5000	0.4545	0.4444	0.4663	3.0079			
Supplier C	0.4000	0.4545	0.4444	0.4330	3.0070			
TOTAL	1.0000	1.0000	1.0000	1.0000				
	Decision Maker 3							
Supplier A	0.0909	0.0625	0.1176	0.0903	3.0139	0.0270	0.5800	0.0465
Supplier B	0.4545	0.3125	0.2941	0.3537	3.0628			
Supplier C	0.4545	0.6250	0.5882	0.5559	3.0850			
TOTAL	1.0000	1.0000	1.0000	1.0000				

Decision maker 1 and 3 had the same sequence as weighted supplier C which was the best performance in delivery criterion with scores of 0.4663 and 0.5559, followed by supplier B at scores 0.4330 and 0.3537, and supplier A had the lowest performance with scores 0.1007 and 0.0903.

For decision maker 2, even weighted the highest delivery score for supplier B but it was a marginal difference to supplier C with scores of 0.4663 and 0.4330. And supplier C was weighed as the lowest score as decision maker 1 and 3 with a score of 1.007.

Figure 4.6: The Average Priority Vector of the Delivery Criterion

DELIVERY	*Decision maker 1*	*Decision maker 2*	*Decision maker 3*	*Average Score*
Supplier A	0.1007	0.1007	0.0903	0.0972
Supplier B	0.4330	0.4663	0.3537	0.4177
Supplier C	0.4663	0.4330	0.5559	0.4851

The average priority vector of delivery criterion on each supplier is shown in Figure 4.6. Supplier C has the highest score in the delivery aspect at 0.4851, followed by supplier B and A which are 0.4177 and 0.0972 respectively. The lead-time of supplier C is approximately 3-7 days which is the shortest when compared with others suppliers, and the lead-time of supplier B and A are 7-10 days and 14-30 days. Supplier C also has more delivery options which are by road, ocean and air, whereas supplier A and B only have two delivery options which are ocean and air.

D. Warranty

Table 4.10: Consistency Analysis of the Warranty Criterion

	Decision Maker 1							
Warranty	Supplier A	Supplier B	Supplier C	Row Average	Consistency Measure	CI	RI	CR
Supplier A	0.1000	0.0769	0.1064	0.0944	3.0036	0.0071	0.5800	0.0122
Supplier B	0.2000	0.1538	0.1489	0.1676	3.0079			
Supplier C	0.7000	0.7692	0.7447	0.7380	3.0311			
TOTAL	1.0000	1.0000	1.0000	1.0000				
	Decision Maker 2							
Supplier A	0.1000	0.0667	0.1091	0.0919	3.0075	0.0163	0.5800	0.0281
Supplier B	0.2000	0.1333	0.1273	0.1535	3.0166			
Supplier C	0.7000	0.8000	0.7636	0.7545	3.0738			
TOTAL	1.0000	1.0000	1.0000	1.0000				
	Decision Maker 3							
Supplier A	0.1250	0.0909	0.1379	0.1179	3.0082	0.0124	0.5800	0.0213
Supplier B	0.2500	0.1818	0.1724	0.2014	3.0161			
Supplier C	0.6250	0.7273	0.6897	0.6807	3.0499			
TOTAL	1.0000	1.0000	1.0000	1.0000				

In terms of warranty criterion, decision makers 1, 2 and 3 weighted the scores and the result were shown as the same sequence as supplier C is the best performance in warranty policy with scores of 0.7380, 0.7545 and 0.6807, followed by supplier B

with scores of 0.1676, 0.1535 and 0.2014, and supplier A has been weighted as the lowest performance with scores of 0.0944, 0.0919 and 0.1179 respectively.

Figure 4.7: The Average Priority Vector of the Warranty

WARRANTY	*Decision maker 1*	*Decision maker 2*	*Decision maker 3*	*Average Score*
Supplier A	0.0944	0.0919	0.1179	0.1014
Supplier B	0.1676	0.1535	0.2014	0.1742
Supplier C	0.7380	0.7545	0.6807	0.7244

The average priority vector of warranty criterion is shown in Figure 4.7, supplier C is the first priority with a score of 0.7244, followed by supplier B and A with scores of 0.1742 and 0.1014 respectively. Supplier C always offers the price with two weeks after receiving the damage warranty, whereas supplier A and B's offer of warranty depends on the purchase value and some lots.

4.2.3 Total Ranking Score for Each Supplier

This step is the process of computation of total score by combining the multiplying matrix of alternative suppliers on each criterion's priority vector with each criterion's priority vector. Then the best alternative is from the highest overall priority ranking value.

The data from the priority vector of the supplier with respect to each criterion in Figure 4.4, 4.5, 4.6 and 4.7 which were computed by multiplying the value of priority vector on each criterion from Figure 4.3, then, the scores were summed to get the total score of each supplier which was weighted by the three decision makers.

Figure 4.8: Total Suppliers' Weighted Scores

Decision Maker 1

	Priority Vector					Priority Vector of each Criterion			Overall Ranking
Supplier	Price	Quality	Delivery	Warranty					
A	0.6334	0.1096	0.1007	0.0944		Price	0.4839		0.3607
B	0.2605	0.3091	0.4330	0.1676	x	Quality	0.3008	=	0.2931
C	0.1061	0.5813	0.4663	0.7380		Delivery	0.1430		0.3462
						Warranty	0.0723		

Decision Maker 2

Supplier	Price	Quality	Delivery	Warranty					
A	0.7766	0.0807	0.1007	0.0919		Price	0.4349		0.3866
B	0.1549	0.2923	0.4663	0.1535	x	Quality	0.3808	=	0.2491
C	0.0685	0.6270	0.4330	0.7545		Delivery	0.1347		0.3643
						Warranty	0.0496		

Decision Maker 3

Supplier	Price	Quality	Delivery	Warranty					
A	0.7151	0.0567	0.0903	0.1179		Price	0.4176		0.3418
B	0.1871	0.2947	0.3537	0.2014	x	Quality	0.3305	=	0.2554
C	0.0978	0.6486	0.5559	0.6807		Delivery	0.1914		0.4029
						Warranty	0.0606		

The overall score of decision maker 1 identified the highest score is supplier A at 0.3607, followed supplier C at 0.3462 and the last is supplier B at 0.2931. Decision maker 2 also ranked supplier A as the best supplier, similar to decision maker 1 with a score of 0.3866, followed by supplier C at 0.3643 and the lowest score is for supplier B at 0.2491. Even the overall score from decision maker 1 and 2 weighted highest for supplier A, but it is an insignificant different with supplier C with the score nearest with supplier A. Anyway, decision maker 3 weighted supplier C as the best supplier at 0.4029, followed by supplier A with a score of 0.3630 and the last for supplier B with a score of 0.2659.

Figure 4.9: Summary of Average Overall Score

	Decision maker 1	*Decision maker 2*	*Decision maker 3*	*Average Score*
Supplier A (China)	0.3607	0.3866	0.3418	**0.3630**
Supplier B (Korea)	0.2931	0.2491	0.2554	**0.2659**
Supplier C (Singapore)	0.3607	0.3643	0.4029	**0.3711**

This Figure showed the average priority vector of the overall score of supplier A, B and C which was weighted by decision maker 1, 2, and 3. Then the researcher can summarize that the most appropriate supplier to supply pipelines to ABC Company is supplier C from Singapore with the highest overall score at 0.3711. The second place supplier is supplier A from China with a score of 0.3630 and the last place is supplier B from Korea with a score of 0.2659.

4.3 Discussion of the Results

From AHP analysis, the price criterion with average score of 0.4455 was found to be the most important factor to consider in the supplier selection process, followed by quality in the second place with a score of 0.3374, delivery and warranty with the score of 0.1564 and 0.0608 respectively as the least important criterion.

The results indicated that the decision makers of ABC Company place the most emphasis on price rather than other criterion. Regarding that the ABC Company is a trading business, the margin would provide direct impact on the Company profits. This fact makes all purchasers keep concerning about this issue in their mind. However, the average score of quality also indicated the importance that the company should not overlook and use as the major determining criterion in supplier selection. And since the oil and gas industry is carefully in safety, so the quality of raw materials is also very important. There is an increasing indication that the quality is an important criterion as price which the company should use quality criterion to consider to select suppliers.

When considering the performance of all suppliers against each criterion, supplier A is distinguished in the competitive price more than other suppliers with the highest score of 0.7084, followed by supplier B with a score of 0.2008 and supplier C who always offered higher bids than others and got the lowest score at 0.0908. Although, supplier C is weak in price, but when considered in others criterion of quality, delivery and warranty, supplier C is the strongest of these criteria and it was weighted as the highest score of quality, delivery and warranty with a score of 0.6190, 0.4851, and 0.7244 respectively.

Supplier B is always in the second place of all criteria since price, quality, delivery and warranty with scores of 0.2008, 0.2987, 0.4177 and 0.1742. Meanwhile, supplier A is very strong in price, but the remaining criteria of quality, delivery and warranty are weighted as the lowest when compared with other suppliers with score of 0.0823, 0.0972 and 0.1014.

Based on the overall score of pipeline suppliers, supplier C, from Singapore, has the best performance as it obtained the highest overall ranking with a score of 0.3711. Thus, supplier C should be selected as the priority supplier. The second place is for supplier A, from China, with an overall score of 0.3630, and the lowest of overall score is supplier B from Korea with a score of 0.2659. Even though supplier C scored the lowest with respect to price criterion this supplier still appeared as the best supplier since the score of quality, delivery and warranty are strong for this supplier. Thus, the combination of all criteria positioned supplier C as the best supplier. Although for most companies the main objective of supplier selection decision is to maximize profit and minimize the total cost of the supply chain, however the focal concentration on quality, delivery and warranty are the criteria that ensures maximization of customer satisfaction. (Gheidar-Kheljani et al., 2010)

4.4 Summary

Among the four criteria of this study, price was the most important criteria used in considering supplier selection of ABC Company, followed by quality, delivery and

warranty respectively. Supplier C from Singapore is weighted as the most appropriate supplier even though it obtained the lowest scored on the price criterion, followed by supplier A from China who always offered at the best price and the last is Supplier B from Korea. Therefore, the most appropriate supplier is considered from the overall performance of each criterion rather than concerned with only one criterion.

CHAPTER V

SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of findings, conclusions and implications based on the analysis from the previous chapter and some limitations and recommendations are identified as guidelines to those interested in supplier selection for future studies.

5.1 Conclusions and Summary of the Findings

The study was considered on the evaluation and supplier selection for a pipeline trading company in Thailand. The process of supplier evaluation and selection are important activities that the purchasing department must integrate into the core strategy when making a decision. As suppliers are observed as critical resources, thus the company has to suitably evaluate and select suppliers to derive the most potential in order to increase profit and customer satisfaction which may lead to sustainable business. For this study, the researcher applied the efficiency tool called AHP to evaluated suppliers because it is a simple and weighted score by pairwise comparison of a nine point scale.

The research focused on a pipeline trading company in Thailand. The four criterions were ranked by price, quality, delivery and warranty which were ranked by six experts in pipelines of the company, and were used in the evaluation. Three sources of pipeline suppliers from China, Korea and Singapore were also evaluated against each criterion.

All computations were completed by Microsoft Excel's matrix multiplication function in order to obtain the priority vector values, and then proof the analysis by consistency measure.

The results indicated that price was the major considered criterion to selecting a pipeline supplier of the company, followed by quality, delivery and warranty. In the meantime, the most appropriate supplier was supplier C from Singapore, who obtained the highest score against quality, delivery and warranty criteria, except the price which weighted as the lowest. The second place was supplier A from China, who was outstanding in the price criterion, while the residuum criteria as quality, delivery and warranty were weighted at the lowest score. The last place was supplier B from Korea, who obtained all criteria scores of price, quality, delivery and warranty the lowest among supplier A and C. This achievement covered the first objective of this study.

Referring to the purchasing values of each supplier of ABC Company in 2012-2013, the highest purchased value was the supplier from China at approximately 53% while the supplier from Korea and Singapore have shared only approximately 23.5%. However, the analysis appeared that the most appropriate supplier was from Singapore replace to the supplier form China.

Therefore, this study may remind the company to consider purchasing process in supplier selection to emphasize more on multi-criteria rather that strictly relying on one criterion as the price.

Nevertheless, this AHP approach has not yet been implemented with ABC Company but it was only analyzed on three suppliers as mentioned earlier. The results referred to that price criterion as the majority weight rather than other criteria. From these criteria results, it is suitable to apply AHP with ABC Company which uses only price criterion to be the main decision tool, but at last, the supplier who offered the lowest price is not the most suitable supplier. So, selecting the right supplier can generate the right quality and the right price on the right time and also indirectly increase customer satisfaction.

Finally, the developed model is evaluated on three supplier selection problem. The results show that AHP is able to support the decision makers to investigate the

strength and weakness of each supplier. In order to apply AHP with ABC Company, the purchasing team should change the way to select supplier that offered only the lowest price. The supplier selection procedure should be improved by bring these four important criteria to periodically evaluate with three suppliers in order to select the most appropriate supplier. The supplier evaluation should be evaluated frequently as monthly or quarterly basis to ensure that the selected supplier is still reliable and serve the material on the standard of criterion requirement. These achievements also covered the second objective of the research.

5.2 Theoretical Implications

This section described about the theoretical implication of supplier evaluation of the pipeline trading company. The researcher developed the supplier selection criteria which were applied from 23 criteria of Dickson (1966), by ranking the importance of each criterion to be appropriately used with the ABC Company. The results generated that the most important criteria of ABC's perspective was the price instead of quality from Dickson's study.

By considering even the price has the most influence in making decisions for supplier selection of ABC Company, but however when applying the AHP approached to evaluate each supplier it appeared that the most appropriate supplier does not offer the best price over others supplier. This result can remind the decision maker of the company that, even though the supplier offered at most competitive price it does not mean that the supplier is the most appropriate, but considering the multi-criteria it would be the right way in which the AHP method that helps the company to set priorities and make the right decisions when more than one criteria are considered.

5.3 Managerial Implications

This study presented a model to evaluate the suppliers which is convincing that it is the right source of selection. The AHP approach is important in defense of the appropriate supply source, especially for the preliminary selection of the right source

to meet with company strategy. Besides, this study can encourage the decision making of procurement management because this model is easy to use by the decision makers and the comparison between various factors is easy to determine. AHP is also facilitating to quantify the judgment and flexibility for purchasing managers and other department managers.

The AHP model is easy to adjust to new situations as in the real life situations, the factor as price, quality, delivery and warranty are very dynamic. So this method of supplier weighting is very flexible.

The main contribution of this study was to identify the important criteria which was used for the supplier selection process. Over reviewing related literature on supplier selection criteria, the researcher identified price, quality, delivery and warranty as the most important criteria for overseas pipeline suppliers.

The second contribution of the study was to apply the APH approached to finding the suitable supplier. From the study, Supplier C from Singapore is the most suitable even though they offered the highest price with the highest overall score at 0.3711 because this supplier has good performance is flexible and has short lead times, less defects and damage, and offered a warranty. Supplier A from China, the overall score is slightly lower than supplier C around 2.18% or score at 0.3630. The Chinese supplier always offered the most competitive price than others, but the low cost source also enabled them to have low product quality. The lowest score is supplier B from Korea at 0.2659, which the average of each criterion is always in the middle between the China and Singapore suppliers. Moreover, as a proof by pairwise comparison, price criterion is not the most influential in selecting a pipeline's supplier; quality, delivery and warranty are taken as serious as the supplier C which offered the highest price became the most suitable supplier.

Lastly, the model is analyzed on three suppliers which the results showed that AHP can assist decision makers to evaluate the strength and weakness of each supplier by comparing the appropriate criteria.

From the analysis of chapter 4 it showed that the ABC Company emphasized on inappropriate suppliers as the highest purchase at around 53% was supplier A from China. However, the results show that the best supply source is supplier C from Singapore who has an average high performance in quality, delivery, warranty, except the price, but the company shared to this supplier only around 23.5%. So the company should take this analysis results to reconsider the important criteria and share the purchasing proportion more with supplier C in order to assist the company preventing loss from repairing and overtime costs, and penalty charges from late deliveries.

5.4 Limitations and Recommendations for Future Research

From the study of supplier selection for pipeline trading company by using AHP approached, the limitation was that the results of priority vector on each criterion cannot be specific to other companies even in the same business. Therefore, the future studies should be inclusive of other pipeline trading businesses.

For further research it could be aimed to improve the analytic hierarchy structure and implement AHP approach in supplier evaluations by using other relevant decision making tools to compare such as linear weighting (LW), total cost of ownership (TCO) and mathematical programming (MP). Furthermore, the analyzing part by Microsoft excel, it generated the accurate result but for the future studies it could apply an expert choice program in order to increase the accuracy and precision to be compared with the Microsoft excel results.

Also, the number of criteria and alternatives should be proper to use for decision makers to make the decision. If the numbers of comparisons are excessive that will bring errors when decision makers weight the score.

Although there are some limitations in the research, the results by AHP approached are still valuable for ABC Company which assists awareness and concern in the supplier selection process that only the best price does not mean best the supplier.

BIBLIOGRAPHY

Al-Harbi, K.(2001). Application of the AHP in project management. *International Journal of Project Management*, 19, 19-27.

Asamoah, D., Annan, J., & Nyarko, S. (2012). AHP approach for supplier evaluation and selection in a Pharmaceutical Manufacturing firm in Ghana. *International Journal of Business and Management*, 7(10), 49-60.

Barabarosoglu, G. & Yazgac, T. (1997). An application of the analytical hierarchy process to the supplier selection problem. *Journal of Production and Inventory Management*, 38(1), 14-21.

Bhutta, K.S. & Huq, F. (2002). Supplier selection problem: a comparison of the total cost of ownership and analytical hierarchy process approaches. *Supply Chain Management: An International Journal*, 7(3), 126-35.

Buffa, F.P. & Jackson, W.M. (1983). A goal programming model for purchase Planning. *Journal of Purchasing and Materials Management*, Fall, 27-34.

Chaudhry, S.S., Forst, F.G., & Zydiak, J.L. (1993). Vendor selection with price breaks. *European Journal of Operational Research*, 70, 52-66.

Choy, K.L., Lee, W.B., & Lo, V. (2003). Design of a case based intelligent supplier relationship management system-the integration of supplier rating system and product coding system. *Expert System with Applications*, 25, 87-100.

Davis, T. (1993). Effective supply chain management. *Sloan Management Review*, 34, 35-46.

De Bore, L., Wegen, L., & Telgen, J. (1998). Outranking methods in support of supplier selection. *European Journal of Purchasing & Supply Management*, 4, 109-18.

Deng, S. & Wortzel, L.H. (1995). Importer purchase behavior: guidelines for Asian exporters'. *Journal of Business Research*, 32(1), 41-7.

Dickson, G.W. (1966). An analysis of vendor selection systems and decisions. *Journal of Purchasing*, 2(1), 5-20.

Gheidar-Kheljani, J., Ghodsypour, S.H., & Ghomi, S.M.T (2010). Supply chain optimization policy for a supplier selection problem: a mathematical programming approach. Iranian Journal of Operations Research, 2, 17-31.

Ghodsypour, S.H. & O'Brien, C. (1998). A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. *International Journal of Production Economics*, 56, 199-212.

Ghodsypour, S.H. & O'Brien, C. (2001). The total cost of logistics in supplier selection under condition of multiple sourcing. *International Journal of Production Economic*, 73, 15-27.

Handfield, R., Walton, S., Sroufe, R., & Melnyk, S. (2002). Appling environmental criteria to supplier assessment: a study in the application of the AHP. *European Journal of Operational Research*, 141, 70-87.

Hines, P. (1994). Can you create your own world class supply chain?, *Purchasing and Supply Management*, September, 30-2.

Karpak, B., Kumcu, E., & Kasuganti, R. (2001). Purchasing materials in the supply chain: managing a multi-objective task. *European Journal of Purchasing & Supply Management*, 7, 209-16.

Karpark, B., Kumcu, E., & Kasuganti, R. (1999). An application of visual interactive goal programming: a case in vendor selection decisions". *Journal of Multi-Criteria Decision Analysis*, 8, 93-105.

Khurrum, S. & Faizul, B. (2002). Supplier selection problem: a comparison of the total cost of ownership and analytic hierarchy process approaches. *Supply Chain Management: An International Journal*, 7(3), 126 – 135.

Liang, W.Y. (2003). The analytic hierarchy process in project evaluation: An R&D case study in Taiwan. *International Journal of Benchmarking*, 10(5), 445-56

Liu, F. & Hui, H. (2005). The voting analytic hierarchy process method for selecting supplier. *International Journal of Production Economics*, 97(3), 308-17.

Min, H. (1994). International supplier selection: a multi-attribute utility approach. *International Journal of Physical Distribution & Logistics Management*, 24(5), 193-98.

Monczka, R.M. & Trecha, S.J. (1988). Cost-based supplier performance evaluation. *Journal of Purchasing and Materials Management*, 24(2), 2-7.

Mummalaneni, V., Dubas, K.M., & Chao, C. (1996). Chinese purchasing managers preference in supplier selection. *Industrial Marketing Management*, 25(2), 115-24.

Nydick, R.L. & Hill, R.P. (1992). Using the analytical hierarchy process to structure the supplier selection procedure. *International Journal of Purchasing and Material*, 28(2), 31-6.

Pan, A.C. (1989). Allocation of order quantity among suppliers. *Journal of Purchasing and Materials Management*, Fall, 36-9.

Render, B. & Stair, R.M. (2000). *Quantitative analysis for management*. New Jersey, NJ: Prentice Hall.

Roodhooft, F. & Konings, J. (1996). Vendor selection and evaluation: an activity based costing approach. *European Journal of Operational Research*, 96, 97-102.

Rosenthal, E.C., Zydiak, J.L., & Chaudhry, S.S. (1995). Vendor selection with Bundling. *Decision Sciences*, 26(1), 35-48.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*. New York, NY: McGraw-Hill

Saaty, T. L. (2000). *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*. Pittsburgh,PA: RWS Publication.

Smytka, D.L. & Clemens, M.W. (1993). Total cost supplier selection model: a case study". *Journal of Purchasing and Materials Management*, 29(1), 42-9.

Tam, M.C.Y. & Tummala, V.M.R. (2001). An application of the AHP in vendor selection of a telecommunications system. *Omega*, 29, 171-82.

Taylor, B. W. (2010). *Introduction to management science*. New Jersey, NJ: Pearson Education Inc

Timmerman, E. (1986). An approach to vendor performance evaluation. *Journal of Purchasing and Material Management*, 26(4), 2-8.

Weber, C.A., Current, J.R., & Benton, W.C. (1991). Vendor selection criteria and methods. *European Journal of Operational Research*, 50(1), 2-18.

Wong, J.K. & Li, H. (2007). Application of the analytic hierarchy process (AHP) in multi-criteria analysis of the selection of intelligent building systems. *Building and Environment*, 43(1), 108-25.

Yu, X. & Jing, S. (2004). A decision model for supplier selection considering trust. *Chinese Business Review*, 3(6),15-20.

Yurdakul, M. (2004). AHP as a strategic decision-making tool to justify machine tool selection. *Journal of Materials Processing Technology*, 146(3), 365-76.

Yusuff, R.D., Poh Yee, K., & Hashmi, M.S.J. (2001). A preliminary study on the potential use of the analytical hierarchical process (AHP) to predict advanced manufacturing technology (AMT) implementation. *Robotics and Computer-Integrated Manufacturing*, 17(5). 421-27

Zhang, Z., Lei, J., Cao, N., & Ng, K. (2003). Evolution of supplier selection criteria and methods. *European Journal of Operational Research*, 4, 335-342.

APPENDICES

APPENDIX A

Supplier Evaluation Form

Supplier Evaluation Form

Decision Maker Information

Name:_____ Position:_____

Company:_____ Date:_____

Explanation

This questionnaire applies the Analytic Hierarchy Process (AHP) to make pairwise comparison among the criteria and alternative suppliers of ABC Company.

The questionnaire can be divided into 2 parts.

Part 1: Decision maker will make judgment about the relative importance of all criteria which relevant to contribution to the objective.

Part 2: Decision maker will make judgment about the relative performance for all alternative suppliers with respect to each criterion.

Note: The weight score is given in the Table A.1.

Table A.1. Pairwise Comparison Scale

Verbal Judgment	*Numerical Judgment*
Extremely Difference	9
Very Strongly to Extremely	8
Very Strongly Difference	7
Strongly to Very Strongly	6
Strongly Difference	5
Moderately to Strongly	4
Moderately Difference	3
Equally to Moderately	2
Equally Difference	1

Compare factor on the left hand side corresponding to factor on right hand side. Suppose that decision maker's judgment factor on the left hand side is more importance or more performance in "extremely difference" level to factor on the right

hand side, then the decision maker choose value of 9 on the left. In the contrary, if the decision maker's judgment factor on left hand side is less importance or less performance in "moderately difference" level to factor on the right hand side, then the decision maker choose value of 3 on the right. Moreover, if the decision maker's judgment factor on left and right hand side are equally important or not difference in performance, then the decision maker choose the value of 1 in the middle of table. The pairwise comparison scale is shows as table A.1.

Part 1: Criteria Pairwise comparison

Comparing the importance of each criterion

Criteria	Criteria Weight Score																Criteria
	Less performance than								Equal	More performance than							
Price	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
Price	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
Price	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Warranties and Claims
Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Warranties and Claims
Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Warranties and Claims

Part 2: Alternative Suppliers Pairwise comparison

2.1 Comparing the performance of Suppliers A, B and C with respect to "Delivery criterion"

Alternative	Alternative Weight Score (Delivery Criterion)																Alternative
	Less performance than								Equal	More performance than							
Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C

2.2 Comparing the performance of Suppliers A, B and C with respect to "Quality criterion"

Alternative	Alternative Weight Score (Quality Criterion)																Alternative
	Less performance than								Equal	More performance than							
Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C

2.3 Comparing the performance of Suppliers A, B and C with respect to "Price criterion"

Alternative	Alternative Weight Score (Price Criterion)																Alternative
									Equal	More performance than							
Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C

2.4 Comparing the performance of Suppliers A, B and C with respect to "Warranty criterion"

Alternative	Alternative Weight Score (Warranty Policy Criterion)																Alternative
									Equal	More performance than							
Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C