DECISION SUPPORT SYSTEM FOR SUPPLIER SELECTION IN GAS PIPELINE INDUSTRY

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กวินกร อัมพรมหา : ระบบการตัดสินใจในการเลือกผู้จัดหาในอุตสาหกรรมท่อส่งก๊าซ. (DECISION SUPPORT SYSTEM FOR SUPPLIER SELECTION IN GAS PIPELINE INDUSTRY) อ.ที่ปรึกษาหลัก : ศ. ดร.ปารเมศ ชุติมา, อ.ที่ปรึกษาร่วม : รศ.ชูเวช ชาญสง่าเวช

งานวิจัยนี้มีวัตถุประสงค์ในการศึกษาและวิเคราะห์ปัจจัยในเชิงปริมาณและเชิงคุณภาพเพื่อเป็นเกณฑ์ในการตัดสินใจเลือกผู้ผลิตและผู้จัดหาท่อก๊าซสำหรับบริษัทอุตสาหกรรมท่อส่งก๊าซ โดยการประยุกต์ใช้เทคนิคกระบวนการลำดับชั้นเชิงวิเคราะห์ (Analytic Hierarchy Process) และโปรแกรมคอมพิวเตอร์สไปซ์ลอร์จิกค์ (SpiceLogic) มาประยุกต์ใช้ในกระบวนการคัดเลือกบริษัทผู้ผลิตท่อแก๊ช กรณีศึกษาสำหรับบริษัทอุตสาหกรรมท่อส่งก๊าซ ในการศึกษาครั้งนี้ได้จัดทำการรวบรวมข้อมูลต่างๆโดยการสัมภาษณ์และตอบแบบสอบถามจากผู้บริหารระดับสูงและผู้เชี่ยวชาญในองค์กรที่อยู่ในอุตสาหกรรมท่อส่งก๊าซ จากการรวบรวมข้อมูลพอว่าปัจจัยสำคัญประกอบไปด้วย 5 ปัจจัยหลัก ได้แก่ คุณภาพในการผลิตขึ้นรูปท่อส่งก๊าซ ความสามารถทางด้านเทคนิค การส่งมอบงาน ราคาของโครงการ และ ความมั่นคงทางการเงิน จากนั้นได้นำปัจจัยเหล่านี้มาการประเมินผู้ผลิตและผู้จัดหาท่อก๊าซก่อนทำการจัดซื้อ โดยทำการให้คะแนนก่อนการสั่งซื้อ ทั้งนี้ไม่เพียงแต่จะช่วยให้บริษัทไม่สูญเสียโอกาสทางธุรกิจ ยังสร้างความเชื่อมั่นให้บริษัทจัดหาผู้ผลิตที่มีประสิทธิภาพ ราคาดี สามารถส่งมอบงานที่มีคุณภาพภายในระยะเวลาที่กำหนดได้

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The objective of this research was to study and analyse both the quantitative and qualitative decision criteria for pipeline fabrication supplier selection in the gas pipeline industry in Rayong, Thailand. The decision-making process was analysed by the Analytic Hierarchy Process technique or AHP and computed using SpiceLogic software. The data collection was carried out by providing questionnaires to experts and specialists at the management level. It was found that the main factors were quality, technical capability, delivery, cost and financial stability. All the main factors were considered with the decision-making process for purchasing and selecting with the best supplier. The results of this research support the company to gain business opportunities as well as a competitive advantage. The results also ensure that the company can procure products that are efficient, have a good price, and able to deliver quality work within the specified time.

Field of Study:	Engineering Management	Student's Signature .....
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		Co-advisor's Signature .....

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Chapter 1: Introduction

1.1 Background of the Research

The case company originated in Germany and was established in 1979. It is a multinational organisation having the largest market share in the industrial gas market. The company shares are traded on all German stock exchanges. The headquarters is located in Germany. There are 2 initial core businesses including the gas division and engineering division.

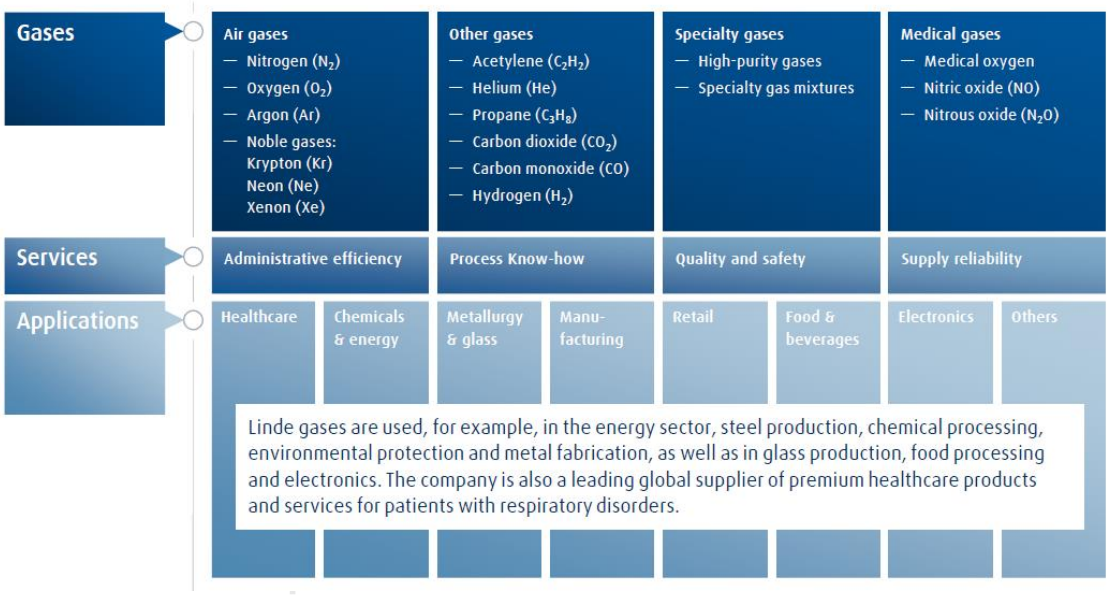


Figure 1: The case company's businesses and product ranges

In Thailand, the case company is a leading manufacturer in the production of industrial gases and has been for more than 40 years. The company does not only produce, but also distributes industrial gases and supplies the gases through pipelines for customers in industrial estate areas. The company also provides a full range of related services, including the installation of gas equipment, process know-how and supply reliability. In 2017, the company won bidding and gained more customers in the Map Ta Phut area. With the new customers, the demand for gas phase nitrogen

(GAN) subsequently increased. A new project for GAN to customers through the pipeline system was also established. The project executives plan to complete the pipeline system construction within the first business quarter of 2019.

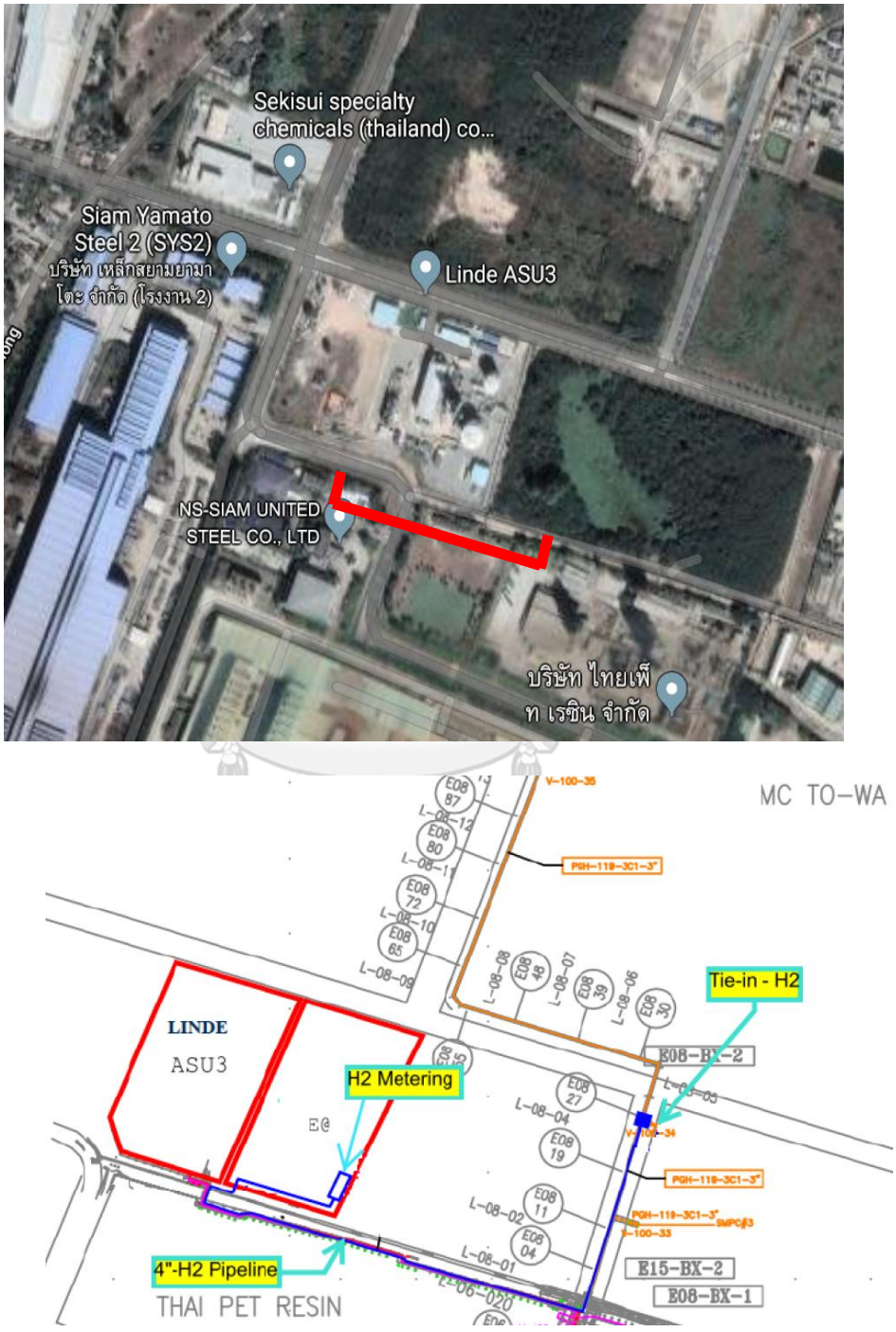


Figure 2: The case company's business operation area in Thailand

According to Figure 2, the majority of suppliers for this new project are in the Rayong area. Pipeline for transporting natural gas is a way that can minimise any effects on the environment. This method is the fastest to transfer gas from one point to another. Supplying gas through pipelines is very reliable because it is free from obstacles in terms of road and ground transport.

The company employs two staffers to conduct local project purchasing and contracting activities. The contractor shall commence the design, fabrication on the commence date, and regularly proceed to the site work with the schedule agreed between the business owner and contractor.

This project requires a pipeline and construction specialist supplier. Therefore, the number of suppliers is limited. Meanwhile, the case company does not have many alternative contractors. Moreover, some suppliers refuse to cooperate and declined a tentative invitation for bidding due to the lack of a long-term relationship. Hence, these external factors and challenges lead to the problem statement of this thesis.

1.2 Statement of the problem

SWOT analysis will be used to identify the problems, both internal and external factors, for this pipeline construction project. The requirement for high-quality suppliers has always been an important issue for many organisation's supply chains, especially in a turbulent business environment. However, the case company has limited procurement staff involved in this project. Further, selection and evaluation of the supplier is not a simple decision that one person can make. It is a multi-criteria problem.

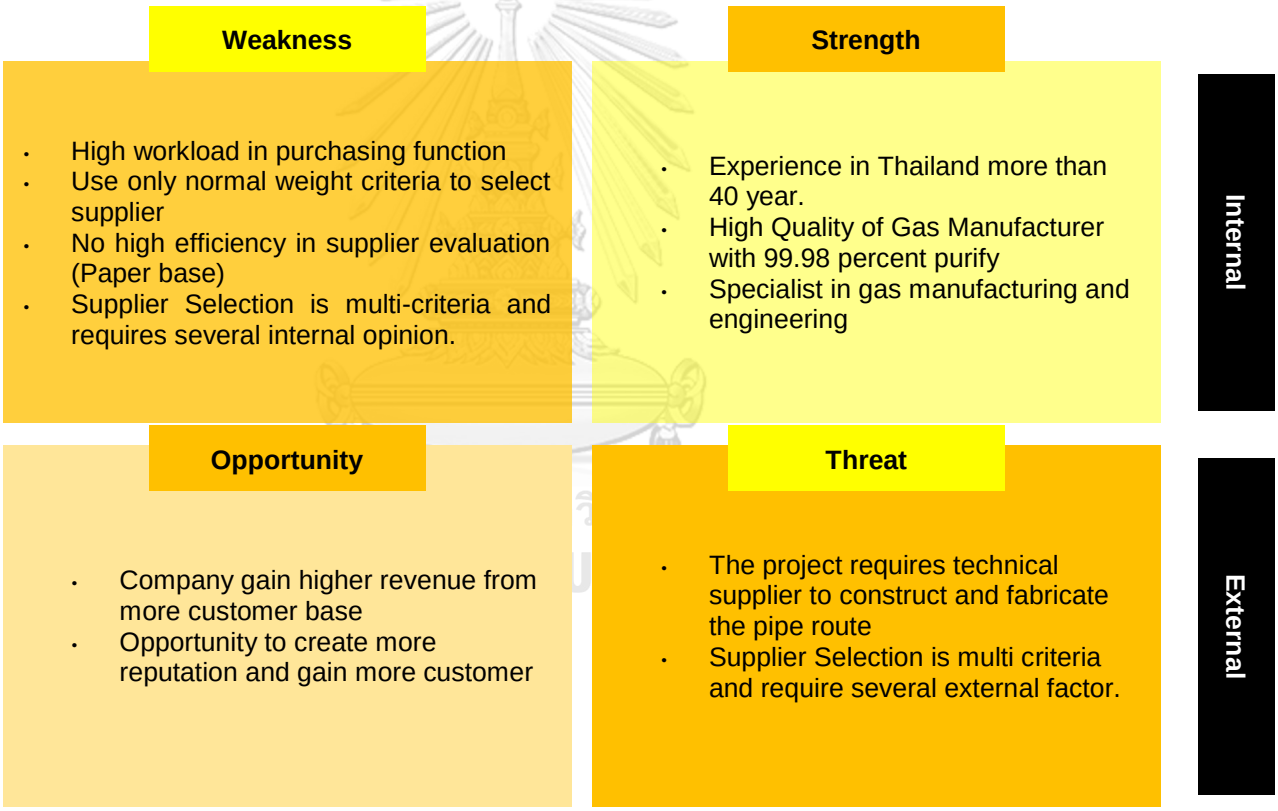


Figure 3: SWOT analysis for new pipeline construction project

There is no doubt that supplier selection does not only involve one decision to make. It has several decisions. Supplier selection is a decision-making process with multiple criteria. The process includes qualitative and quantitative criteria, where the purchaser should be considered.

The most important challenge in supplier selection is the choice of criteria for the evaluation. Supplier decisions are complicated due to the fact that several criteria must be considered in the decision-making process. One of the challenges is how to determine critical criteria to select the most suitable supplier. Every buyer has different expectations from the supplier. Different firms may have different cultural backgrounds, which affects the supplier selection process. Therefore, which criteria are suitable and should be used for evaluation of supplier for the firm is important. The single criteria approach of the lowest cost supplier is more accepted in this competitive environment. The initial 23 critical criteria for supplier selection choice were first introduced in 1960 (Dickson, 1966).

Criteria	Dickson's rank	Criteria	Dickson's rank
Quality	1	Management and organization	13
Delivery	2	Operating controls	14
Performance history	3	Repair service	15
Warranties and claim policies	4	Attitude	16
Production facilities and capacity	5	Impression	17
Price	6	Packaging ability	18
Technical capability	7	Labor relations record	19
Financial position	8	Geographical location	20
Procedural compliance	9	Amount of past business	21
Communication system	10	Training aids	22
Reputation and position in industry	11	Reciprocal arrangements	23
Desire for business	12		

Table 1: Comparison between Dickson and Weber criteria

In practice, the case company uses the Simple Additive Weighting or linear averaging method to select its supplier. It is the most commonly used for supplier selection. The criteria that the case company selects are

- Business Management Score
- Responsiveness Score
- Product/Service Quality Score
- Design standard
- Experience in similar project with Piperack owner and Case Company
- Project management
- Ability to execute, Heavy equipment & Tools
- QC protocol and document control system
- Quality control & team communication
- Safety management and provision
- Competency of execution team
- Documentation & activity report

Criteria	Price	Quality	Deliver	Total Performance
Alternative Supplier	0.4	0.2	0.4	
A	25	20	15	20.0
B	10	30	20	18.0
C	30	10	30	26.0

Table 2: Simple Additive Weighing (Example)

Practice shows that this method has some drawbacks. One drawback of this method is mainly focused on the quantitative criteria, which is easier to be measured. On the other hand, qualitative issues were not included. Selecting an appropriate supplier is a trade-off between influential factors. Therefore, it is challenging for the buyer to choose appropriate criteria to select a suitable supplier.

Another challenge for business management is how to reduce the cost of operation, especially in terms of strategic sourcing. Strategic sourcing leads to several approaches, such as purchasing management, inventory control and partnership. Because of the low level in the relationship with some suppliers, some suppliers decline to be involved in the bidding.

It is evident from the problem statement that the approved and accepted vendor list for the case company failed to meet the company's requirements. However, this problem can be solved by selecting one more suitable and which can satisfy performance. Therefore, some techniques, such as analytic hierarchy process (AHP), will be applied and conducted in this study.

1.3 Objective of the research

The objective of this research is to develop and conduct a supplier selection analysis using the AHP approach to choose the most suitable supplier for the pipeline gas system construction project in Rayong, Thailand.

1.4 Scope of the research

The scope in this research covers the supplier selection process to decide on the most suitable supplier for the new pipeline installation project. This research will be focused on supplier selection and criteria evaluation.

1.4.1 Supplier Selection Scope

The research mainly focuses on the purchasing activity, while the project execution team will focus on the time management and budget control. The other function will not be included in this thesis, unless there is direct impact to the procurement function and an impact on supplier selection performance. This research covers the direct purchasing of materials for the pipeline system. However, most of the critical material will be subcontracted and purchased by the contractor. The supplier in this research is a local contractor who can support the construction project. Suppliers must understand and be able to handle the job specifications as well as the scope in this research.

Therefore, this research only consists of two main functions, which are procurement and project teams. The criteria will be selected by company experts, including the purchasing manager, purchasing country head and project executive manager.

1.5 Expected benefit

- To understand what is the most important factor used to evaluate a Pipeline Fabrication Supplier
- To be able to select and evaluate a suitable supplier with the AHP process

Chapter 2: Literature Review

This chapter reviews the existing literature that served as the basis for this research. The review consists of relevant models, approaches, journal articles and case study.

2.1 General Procurement Process

Currently, businesses are competing with competitors by developing the capability to better achieve customer satisfaction and meet demand. In terms of supply chain management, there are various activities that a company should implement, such as customer service support, strategic purchasing and procurement, inventory management, etc. Apart from the previously mentioned activities, purchasing and procurement is an activity that companies have been focusing on because of its significant effect on the company's overall profit and loss (Bevilacqua and Petroni, 2002; Ellram & Carr, 1994). In the procurement process, there are six order decisions to be followed (Aissaoui, Haouari, & Hassini, 2007), as represented in Figure 4.

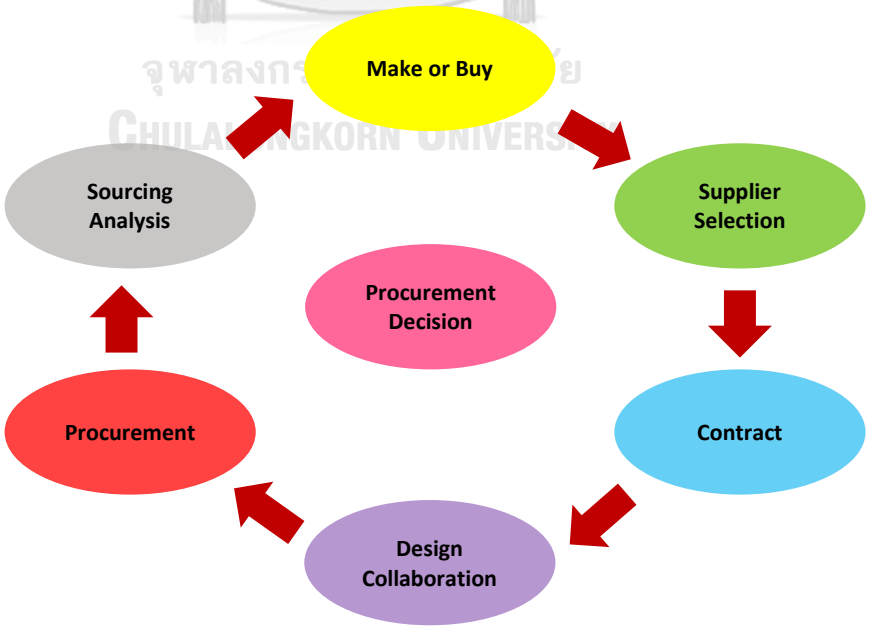


Figure 4: Processes in purchasing and procurement activity *(Aissaoui et al., 2007)*

According to Figure 4, once the organisation has made a decision concerning whether to produce a product or buy from an outside supplier, the next step is the supplier selection process, which means that the company will select the most appropriate and highly potential supplier who could provide materials, products or services to the buyer with high quality and within the timeline of the project schedule. The next step is to design the contract. The designed contract will focus on negotiation with the awarded supplier. The design collaboration involves working with the supplier to meet product and project requirements. After the completion of procurement, the firm should evaluate the procurement activity and supplier performance in order to form the long-term partnership and relationship.

Procurement is one very important activity for company management. In supply chain management, the importance of procuring raw material and good quality product in order to meet the needs of customers is recognised, though the changes have focused on prices for the good quality of products. In procurement, there must be a process for deciding on raw materials and deciding to select distributors of quality raw materials at an acceptable price. Most importantly, there must be a system used to check the quality of raw materials and suppliers, which will result in lower cost of logistic management.

One of the most important factors to improve supply chain management is to select the right supplier and contractor. Sometimes, the purchasing cost contributes more than 50 per cent of the total cost of the product that the company sold (Humphreys, 2007). Thus, it can be concluded that supplier performance has a direct effect on organisational performance.

2.1.1 Procurement Management

The procurement department is responsible for providing products and services to meet the needs of the customers; this case refers to the requester. The procurement concept consists of 6R + 1. The main duties of the purchasing department are listed below (De Boer, 2001).

1. Right Quality procurement means procurement of raw materials, products, or services that meet the qualifications required and meet the set of company standards and regulations.

2. Right Quantity refers to the procurement that has to consider the quantity of the order. The procurement department must purchase raw materials or products in the desired quantity or amount that is not missing or over quantity using the principles of Economic Order Quantity (EOQ) or Material Resource Planning (MRP) to support and consider the cost of product ownership.

3. Right Place mean that the supplier must deliver the product or service exactly on time with a reliable transportation system and not cause damage or loss in the exactly specified location.

4. Right Time is the principle for considering the time that must be procured by using the Re-order Point (ROP) principle to calculate in order to obtain raw materials, products or services at the right time

5. The right price (Right Price) can be described as the factor that most businesses are most focused on because it will directly affect the cost of the product and the expense that is incurred by the organisation. As a result, several businesses have moved to focus on methods of cost and price analysis or considering whether to purchase or rent machinery or equipment to perform short-term activities.

6. Right Source or (Right Supplier) Procurement should respond to buy products at the right supplier base on location strategy or negotiation skill. Most buyers purchase products from a reliable source. In this case, it means buying from the same source or a source that provides an attractive discount in terms of the cost of the product or quality.

7. Right Purchaser means that the procurement department should hire the right person to work in procurement, meaning the knowledge, qualifications and experience in purchasing necessary as well as having good negotiation skills.

2.2 Supplier Selection Criteria

The supplier selection processes were segregated into four phases which define the problem, formulate the criteria of selection, pre-select the supplier and final making decision respectively (De Boer, 2001). One of the challenges is how to determine critical criteria to select the most suitable supplier.

The initial 23 critical criteria of supplier selection choice were first introduced in 1960 (Dickson, 1966). Several companies continue to use Dickson's criteria to evaluate suppliers. The questionnaire asking about the 23-critical factor that affects the supplier selection was sent to purchasing agents across the United States and Canada. From the 23 lists, the survey revealed that the top 6 important criteria were quality, delivery, performance, warranties and claim policies, production facilities and capacity and price.

Notwithstanding that this survey was created in 1966, some criteria are still valid today. After Dickinson's theory, Weber conducted research and reviewed the criteria from 1966 to 1990 (Weber, 1991). It is clear from several researches that price, delivery time and quality are considered the top 3 basic criteria, while production capacity and technical specification are the next two top criteria. Because of the different industries and environments, different criteria will be applied.

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

Table 3: Comparison between Dickson and Weber criteria (Weber, 1991).

It is noticeable later that the number of critical criteria has been increasing with more complex decision structure. Apart from the consideration of basic criteria mentioned earlier, it is also considered as selection criteria to select a supplier in electronic business (Gencer and Gürpinar, 2007). Supplier selection is a decision-making process under multiple criteria. The process includes qualitative and quantitative criteria where the purchaser should be considered. Selecting an appropriate supplier is a trade-off among the influential factors.

2.3 Supplier Selection and performance evaluation Method

The supplier selection processes were classified into 4 phases (De Boer, 2001), as shown in Figure 5. Starting with the define problem, the company must define the problem(s) involved in the project. The next step is to formulate the criteria before the qualifying process. The qualifying process is a part of the selection process to select a suitable supplier and obtain a set of potential suppliers, referred to as "pre-select suppliers" to reduce the number of possible suppliers.

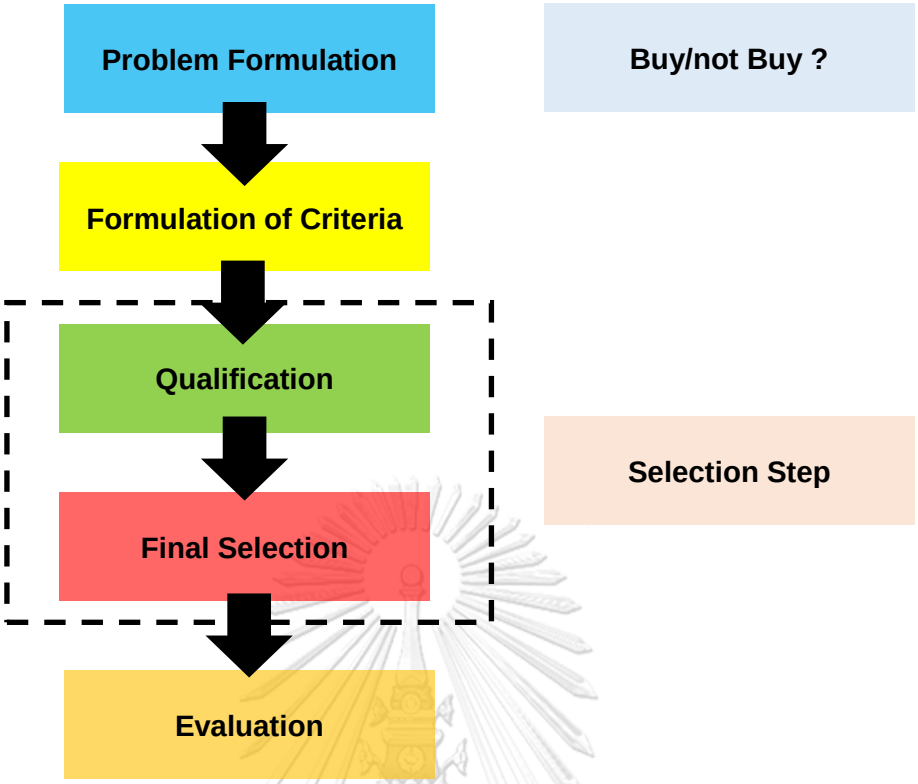


Figure 5: Supplier Selection Method (De Boer, 2001).

As illustrated from the above figure, it shows that there are two steps in the selection. Hence, this topic is separated into 2 parts. The first part is the method to pre-qualify a supplier. The second is the method to make a final selection.

2.3.1 Method of Supplier's Pre-qualification Phase

Pre-qualification phase or pre-selection phase is the process to decrease the number of suppliers before making a final decision. Therefore, the main concept of this phase is to categorise the suppliers into groups. There are several approaches in this phase, which are:

- Categorical methods
- Simple Additive Weighting
- Case based reasoning (CBR).

Categorical Methods

Categorical method is a method to evaluate a supplier's performance. The decision-maker evaluates each performance on each criterion as either, good (positive), moderate (neutral) or inefficient (negative), and summarises the overall rating (Timmerman, 1986).

Supplier	**Price**	**Quality**	**Lead Time**	**Total**
A	Good (+)	Inefficient (-)	Moderate (0)	0
B	Moderate (0)	Good (+)	Good (+)	++
C	Moderate (0)	Inefficient (-)	Moderate (0)	-

Figure 6: Example of Categorical Methods

The benefits of this method include ease of implementation and low expense. However, the drawback of this method is that all criteria are assumed to have the same important weight in the reflection of actual decision-making. It also lacks detail. The rating is dependent on the evaluator. Therefore, it is important to select expert and experienced personnel for this method.

Simple Additive Weighting

Simple Additive Weighting or linear averaging method is a multi-criteria decision making method (MCDM). It is the most commonly used method for supplier selection *(Bendon, 2007).* The critical criteria such as price, quality and delivery are generally used in this model. The weight of each criterion varies based on the different importance levels of the organisation.

- The criteria of this SAW method follows the below step.
- Assign the weight for each criteria based on the judgment of the management level. The sum should be 100.
- Determine and give a rating for each criteria
- Multiply the performance rating for each criteria with the weight, respectively
- Add the weight rating to receive the total performance rating

• Criteria	Price	Quality	Deliver	Total Performance
Alternative Supplier	0.4	0.2	0.4	
A	25	20	15	20.0
B	10	30	20	18.0
C	30	10	30	26.0

Table 4: Simple Additive Weighing

This model is simple for implementation. The model is highly flexible to support a wide range of critical criteria. The drawback of this method is mainly focused on the quantitative criteria, which is easier to be measured. On the other hand, qualitative issues were not included.

Case Based Reasoning (CBR)

Case Based Reasoning is used to regain a list of potential suppliers in the pre-selection phase by using neural network engine (NNE). This method must work with artificial intelligence (AI) technique to solve the problem by using previous similar situations and in a huge database. The drawback of this method is that an enormous database is required and it is not applicable for new projects or non-repeated orders.

2.4 Supplier Selection

Selecting the right supplier is important because it leads to reductions in costs, the prevention of product issues and reprocess for defects, and developing improvements in the supply chain. Most studies are concerned with the selection of new suppliers (Peter and Luise, 2003).

The primary aims of the supplier evaluation process include reducing the risk in procurement, ensuring that suppliers who do business with the case company can meet the company's requirements (Humphreys et al., 1998), and identifying opportunities for long-term relationships and improvement (Singerpurwalla, 1999).

Characteristics	Principle
Comprehensive	The users can understand exactly the meaning of scales and items.
Objective	Using a scoring system is required to clearly define the different meaning of each value on a measurement scale. Objective means making a quantitative scale to evaluate performance attributes.
Reliability	Reliable supplier evaluations should have well-defined measures and well-understood items and scales. Different people or groups review the same items and the same measurement scales will reach the same conclusion.
Flexibility	The evaluation process should provide some flexibility in adjusting the performance categories and weights assigned to each category, regarding to their importance. The most important categories will get a higher weight.
Mathematically straightforward	The application of weights and scales should be simple so that each individual using the evaluation is able to understand the mechanics of the scoring and selection process.

Figure 7: Characteristics of supplier evaluation (Monczka et al., 2002).

In order to identify the supplier evaluation, an effective supplier evaluation process should have certain characteristics to follow (Monczka et al., 2002).

2.4.1 Method of Supplier's Final Decision Phase

The final decision phase is the stage to select the most suitable supplier. This stage can either be done before or after finishing the pre-quality stage. The most commonly used methods to make final decisions in supplier selection problem are as follows:

- Multi Criteria Decision Making (MCDM) Technique
    - Analytic Hierarchy Process (AHP)
    - Analytic Network Process (ANP)
    - Fuzzy Theory

Multi Criteria Decision Making (MCDM) Technique

Supplier selection is a multi-criteria decision-making problem. Several MCDM techniques have been applied to tackle this decision problem, such as analytic hierarchy process (AHP), analytic network process (Eshtehardian, Ghodousi, & Bejanpour) and fuzzy theory. In AHP and ANP approaches, all criteria are weighed, while alternatives are ranked based on pairwise comparison. These methods can deal with both the quantitative and qualitative criteria as well as simplify complex problems into hierarchical form.

AHP has been established since 1980 (Saaty, 1980). AHP provides a logical method for determining intangibles and complex decisions in hierarchical form. AHP contains several steps. Firstly, it decomposes the complex problem into different levels within a hierarchy. The objective or goal was started from the top level. The

second level represents the multiple criteria that will be considered for evaluation. The third level indicates the alternatives being evaluated. Moreover, the structure level can be modified to have more than just three levels. This is to capture the additional specific problem decision.

The fundamental concept of the Analytic Hierarchy Process is to gain an important weight of each critical criterion, then calculate the score for each alternative based on all criteria and rank the alternatives. The steps of AHP can be summarised into steps as follows:

- **Construct the decision hierarchy model**

It is important to clearly understand the goal and the problem at level one. All the criteria must be selected carefully to determine and construct an alternative, then construct the hierarchy model, as shown in Figure 8. (Saaty, 1980).

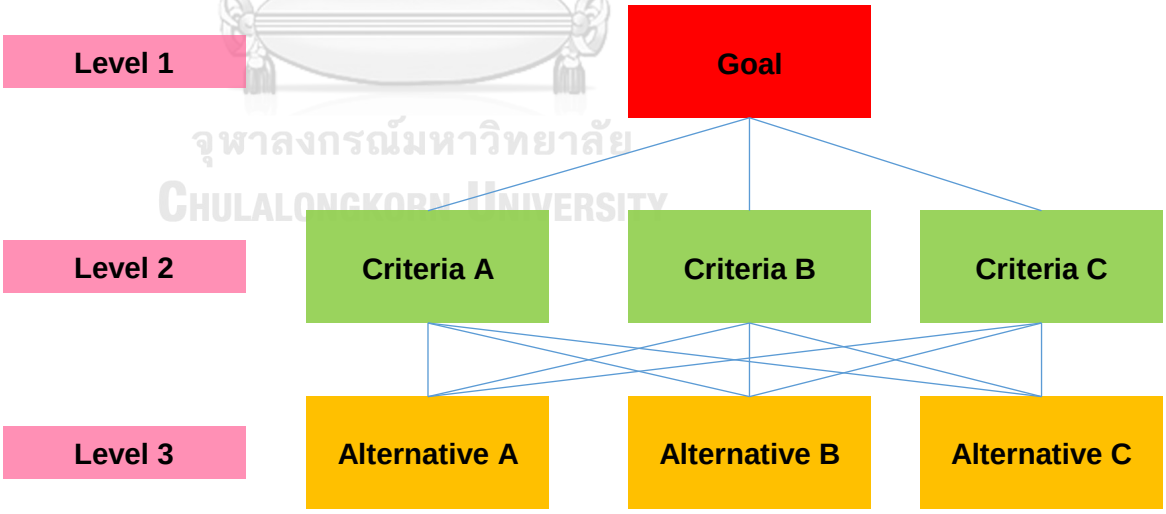


Figure 8: Example of Hierarchy Model (Saaty, 1980).

- **Make pairwise comparisons of criteria and alternatives in the same level**

AHP identifies each step as the hierarchy level. Therefore, pairwise comparison needs to be used. The pairwise will be calculated from the top to the bottom of the model, which will start from the second level and third level, respectively. The equation to identify how many pairs are needed to calculate is shown below:

$$\frac{n^2 - n}{2} \tag{2.1}$$

Where n = number of criteria in that particular level

Referring to Figure 8, the second level consists of 3 critical criteria. Then, we have 3 pairs to compare. To make pairwise comparisons, the decision maker is required to give preference numbers to compare between two criteria. In general, the scale is ranked from number 1-9, as shown in Figure 9.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the goal
2	Weak or slight	
3	Moderate importance	The decision maker slightly prefer one factor to another
4	Moderate plus	
5	Strong importance	The decision maker strongly prefer one factor to another
6	Strong plus	
7	Very strong or demonstrated importance	The decision maker very strongly prefer one factor to another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one factor over another is of the highest possible order of affirmation

Figure 9: scale is ranking in number 1-9 (Decision model structure)

From the decision model structure in Figure 8, we can construct a pairwise matrix of the criteria, as shown in Table 5.

Goal	Criteria A	Criteria B	Criteria C
Criteria A	1	1/2	1/4
Criteria B	2	1	1/2
Criteria C	4	2	1

Table 5: Pairwise Matrix Example

After pairwise comparisons have been completed, consistency must be checked before calculating the important weights as well as alternative scores. This can be judged by the consistency ratio (CR), which is computed by the following equation:

$$CR = \frac{CI}{RI} \tag{2.2}$$

$$CI = \frac{\lambda_{max} - n}{n} \tag{2.3}$$

Where CR is consistency ratio

CI is consistency index

RI is random consistency index

λ_{max} is the largest Eigen value

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

The value of RI is related to the number of elements in pairwise matrix (n) and will be used from Table 06. It should be noted that the consistency ratio is lower than 0.10, which means the results of comparison are consistent.

n	1	2	3	4	5	6	7	8	9	10
CI(Theory)	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Table 6: The value of Random Consistency Index (Golden and Wang, 1990)

2.4.2 Literature Review

In general practice, the acceptance for an inconsistency should not be greater than 10%. In other words, the value of CI should be smaller or equal to 0.1. If CR of each pairwise matrix is acceptable, then the results are transformed into important weights. The total score of each alternative is calculated in the final step.

According to the studying of researches and related literatures, analytical hierarchical techniques are used for various decision-making processes. Quantitative and qualitative factors are used as criteria for making decisions as well as finding the weight of importance by comparing with the comparison method.

Ghodsypour and O'Brien (1998) used AHP and Linear Programming Model Development in order to find the best supplier and the right order value for each supplier. They consider the weight of importance of the each criterion. The most important criteria were cost, followed by quality and service. Then, the suppliers will be selected based on linear programs to calculate the total value of the order.

Xia and Wu (2007) selected suppliers based on discounts from the total value of orders. Therefore, there are two main questions in their research, including: which supplier to choose and which value to buy? Their research was divided into 2 analysis

steps. The first step was mainly to use the AHP to select the suppliers based on the weight and importance of criteria. The most important weight was cost, followed by service and quality. The second step is supplier selection based on discounts using MATLAB program to identify and calculate the order value of each supplier.

Nataraj (2005) applied AHP as a decision guideline in the Petroleum Pipeline industry for stages of project planning. The literature focused on the hierarchy of the selection for a pipeline route. The most important weights were the length of the pipe, operability, maintainability, approachability, constructability, and environment.

Jin and Lu (2013) stated that supplier selection is an important decision for purchasers. AHP is an appropriate method which is suitable for the supplier selection problem. In this sample research, a comparison between two methods using AHP and fuzzy AHP has been conducted for an auto-parts enterprise supplier. Both approaches are theoretically similar. The criteria used in this research include Cost Index, Enterprise scale, Product quality, Logistic equipment Technology and Service Level. As a result, the study concentrates on the auto-parts enterprise as a major priority.

Giridhar Kamath, Rakesh Naik and Shiva Prasad H C (2016) studied the supplier's evaluation using AHP for steel pipe manufacturing company in order to improve the organisation's supply chain performance. The study also focused on determining the best raw material supply vendor. The study shows some limitations, such as the possibility of response bias. The most important criteria are Quality, Cost, Delivery and Vendor Relationship Management (VRM).

Stefania Benuccia and Fabrizio Talloneb (2014) conducted a case study for alternative selection using the Analytic Hierarchy Process for a gas route in Italy. The aims of the study were to highlight the strengths and weaknesses of the possible

alternatives and select the most suitable pipeline route using AHP. The study is consistent with the Risk Matrix used for the assessment. Criteria ranking has been performed on 4 criteria including People safety, Environment Impact, Technical challenge, and Impact on Schedule. Overall, the study pays more attention more to people safety as the most important criteria that affect the construction of the pipeline route.

Colin Nithin Nonis, Koshy Varghese and K S Suresh (2007) studied the pipeline alignment. The study focused on identifying the different criteria that affect the pipeline route in the Indian country and developing the pipe line cross-country. When a new pipeline path is initiated, the list of multiple criteria that need to be avoided is created. The study lists the criteria that need to be abided by, such as steep slope area, road cross crossing, railway crossing, river crossing, forest area, and highland cost area. The study applies the AHP method to question expert opinions to derive weightages for the factors affecting the route.

Farhaj Ishtiaq and Mirza Jahanzaib (2016) used the application of AHP to identify the factors affecting the Oil and Gas Sector. The factors are separated into three groups including attributes of project staff, project planning process and assessment of project quality. Results of AHP method including question air to expert concluded that, project completion within time and budget are the most important choices for development in project execution performance of oil and gas projects.

Chapter 3: Methodology

The process of choosing the most appropriate method will be described in the research framework. Then, the initial set of criteria is shown along with the AHP model.

3.1 Research Framework and Research Methodology

In order to achieve the objective of this research, there are several steps, as shown in Figure 10.

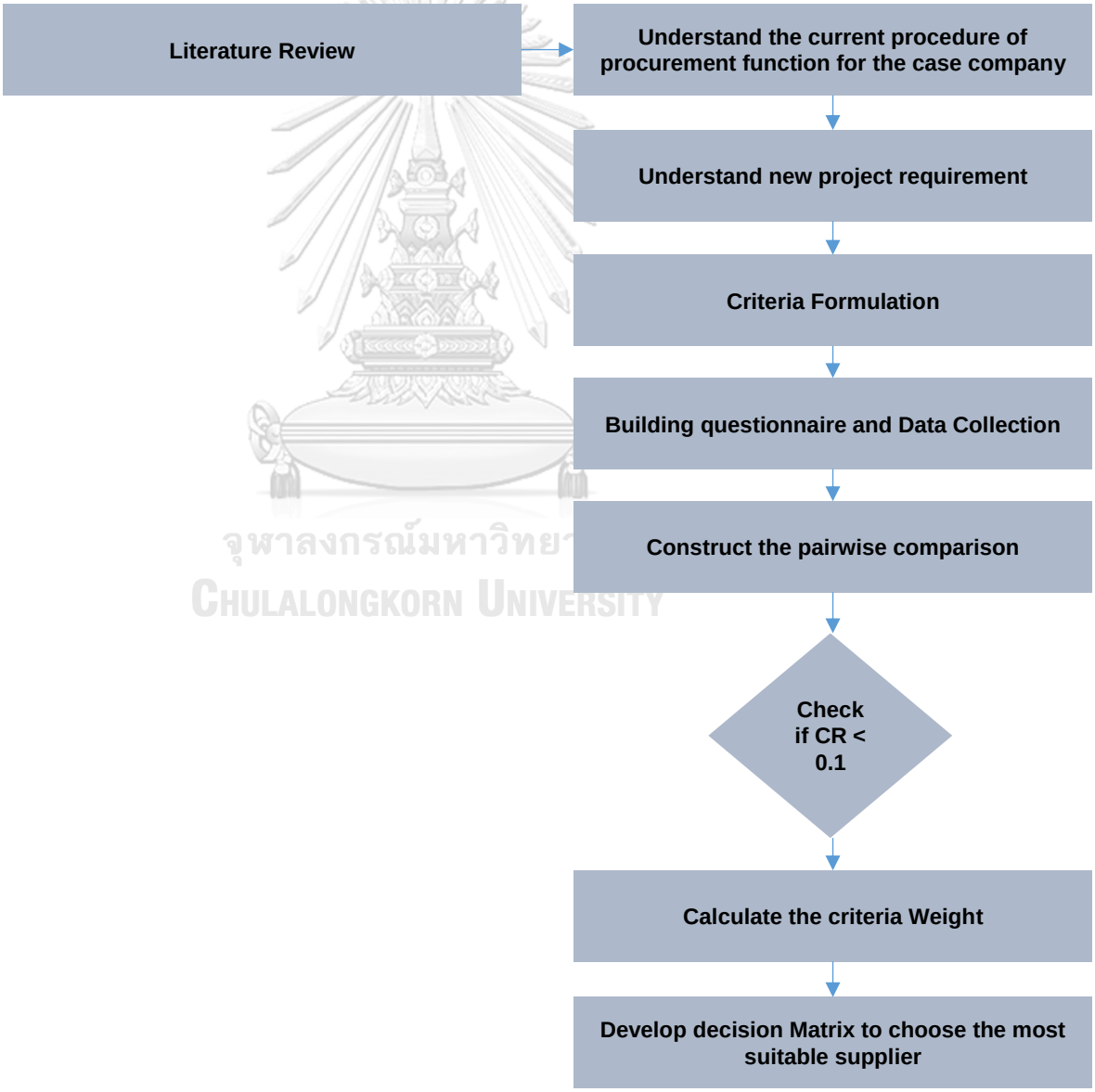


Figure 10: Research Framework

This research study has preparation methods and procedures as follows:

1. Study of theories and related research, including the selection of a fabrication pipeline supplier, Analytical Hierarchy Process (AHP), and Application Program.

2. Study of both quantitative and qualitative factors that affect the supplier selection decision.

3. Design the hierarchy structure for the selection of suppliers including designing the questionnaire to be suitable and covering the research topic.

4. Analyse and collect data by comparing and determining of the weight of each factor. In this step, it will ask for opinions from the executives and employees in the procurement department expertise and other business-related departments.

5. Evaluate the consistency of decision-making in the sequence of alternative factors as well as analyse sensitivity to changes in various key factors by using Microsoft Excel program.

6. Analyse and summarise the decision of choosing a supplier for Pipeline Fabrication according to the analytical hierarchy process (AHP).

To respond to the research objectives, the research scope is illustrated in Figure 11.The first part is to determine the critical criteria and weight criteria because the criteria in supplier selection have an effect on each other (Eshtehardian et al., 2013). In other words, the criteria are interrelated. Therefore, the preference of criteria in this part is compared and analysed by using the AHP technique.

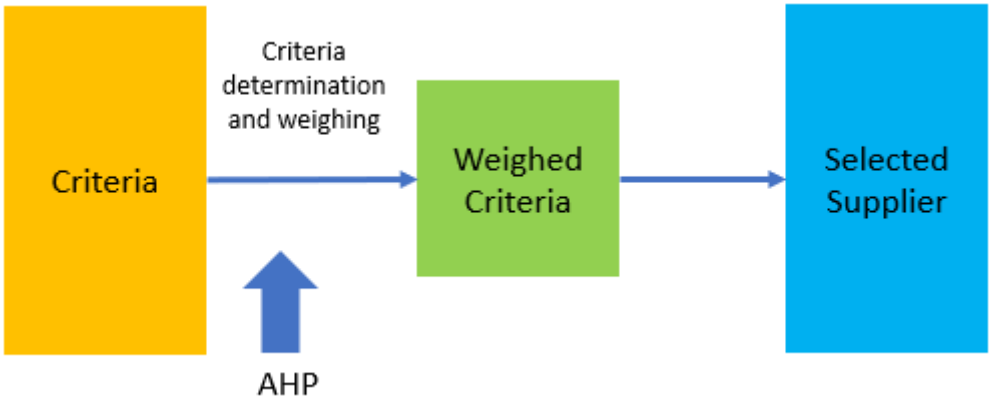


Figure 11: Research Framework for criteria formulation

3.2 Understanding the current procedure of procurement function in the case company

The case company Procurement Standard has been established to identify the tasks, responsibilities and purposes of all relevant procurement processes. Procurement organisation has two principle areas of focus, which are:

- Strategic Procurement
- Procurement Execution

The first group primarily deals with the "Source to Contract" processes and the second with Order to Contract and Purchase to Pay. Procurement and purchasing processes in the case company are similar to most of the other procurement processes.

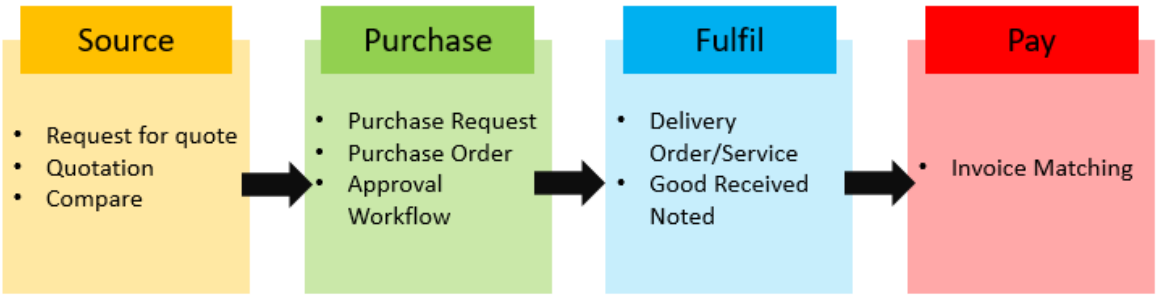


Figure 12: General Procurement process

However, the case company has the commitment amount level. This will affect the approval hierarchy and approval requirement. The more money for the project and material, the more process and more people will be involved. The below table illustrates the criteria for the approval process.

Commitment Amount	User Participate	Procurement Participants	Approval requirement
€0 - <€5,000	Team Leader	Buyer	E-mail approvals from Procurement
			Quotation
			No need for comparison
€5,000 - <€25,000	Team Leader	Procurement Manger	Email approvals from Procurement
			Full Scope of work
			At least 3 Potential Supplier
			Full Scope work
More than €25,000	CAPEX Owner or Team Leader	Head Of Procurement Centre and Strategic Manager	E-mail Approval from Procurement
			Comparison of Bidding (COB)
			Full Scope work
			RFQ
			At least 3 Potential Supplier

Table 7: Cased company approval criteria

After sourcing/tendering, Group Procurement must prepare a Comparison of Bids (COB) unless the sourcing is carried out for a concrete demand of low value. The purpose of the COB is to document how Procurement compares the received quotes to ensure the buyer drew the right conclusion from business perspective considering not only price, but Total Cost/Value of Ownership (TCO / TVO).

The COB must show that quotes were requested from at least three bidders, unless there are market restrictions, e.g. the market is a monopoly. It must be kept in a system and shall be available on request for 5 years. COB value thresholds are

country specific, but must not allow demands worth more than 25.000 € or equivalent to be processed without COB.

3.3 Understanding the project requirement

With regard to spending analysis, this is the process of analysing corporate spending data for the purpose of cost reduction (Pantavanij, 2005). The spending data and requirement will be classified into 5 primary dimensions. It can be seen that categorised spending data and requirement will be analysed to determine the standard specification, volume, and price, which are collected from the market price as well as budget.

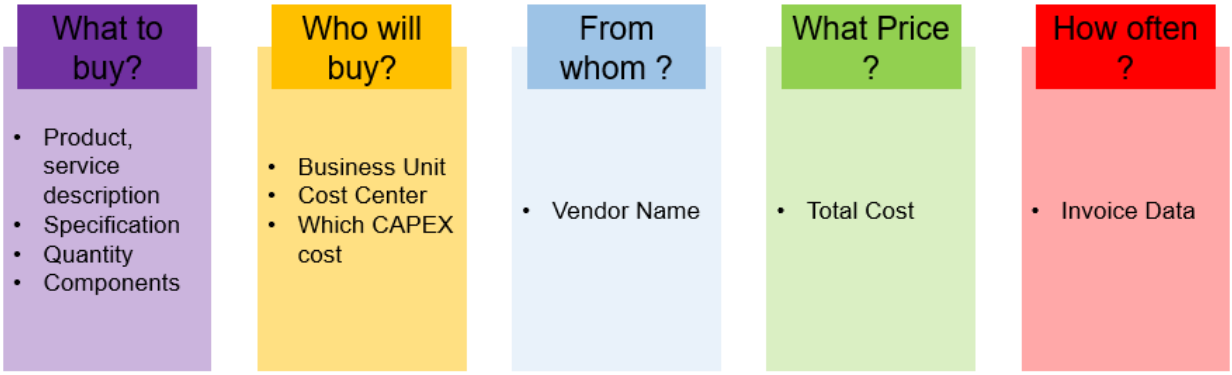


Figure 13: Categorised data

The case company scope and requirements

The case company is now seeking to establish successful vendor to fabricate and install Nitrogen product pipeline and metering at Map Ta Phut Industrial Estate Area, Rayong, Thailand. The basic scope of the work to be carried out by the contractor includes Civil, Mechanical and Equipment & Piping installation sections.

Engineering design, Civil, Mechanical and Equipment & Piping installation section

- Engineering design of civil, piping and steel structure for Hydrogen pipeline and gases metering station from tie in future valve to Customer plant.
- Construction of 4-inch C.S. Hydrogen pipeline from tie in future valve at to Hydrogen gases metering station at EBI plant.
- Contractor scope shall include the fabrication and installation of pipeline and pipe rack extension, foundation and pipe support installation in each specific area.
- Earthwork Excavation and Reinstatement work
- Contractor shall supply and manage scaffolding work during construction activity.
- Organise safety induction apply to all areas of construction project with coordinate with EFT representative, SHEQ from Linde Representative or from legal organisation when necessary
- Manage, organise and planning of construction works for pre-planned and day-today activities on behalf of Linde.
- Coordinate with authorised organisations such as Industrial Estate in MTP, WHA EIE, AIE and EBI for permission of pipeline construction work and pipe rack owners for authorisation.
- Manage and control all documents concerning the project in order to control project drawings such as work instruction, datasheet, operating manual, inspection, and test certificate by hand for project handover document.

Construction Management

The contractor will provide a comprehensive construction management team on the site to manage, supervise and administer the appointed construction subcontractors for both the office site and off-site work. All contractor staff will be suitably experienced and qualified for the appointment.

Contractor will be completely responsible for construction management on the site,

including:

- Fencing of construction area and provision of temporary site accommodation and facilities for construction management staff
- Coordination of construction subcontractors
- Schedule, cost reporting and control
- Quality control/assurance, including technical queries/deviations from drawings
- Materials control, including receipt, storage and issue of cased company's supplied

  equipment and materials
- Health and Safety
- General site administration and document control

3.4 Decision criteria for fabrication pipeline supplier for gas pipeline industry

3.4.1 General forms of decision making for supplier selection

Kepner and Tregoe (1965) suggested ideas for the determination of criteria by two objectives, starting with the elimination of selection steps that are not feasible. Then, the decision maker will be able to choose from the remaining possible criteria. Such criteria are divided into 2 types, which are “Must Criteria” and “Want Criteria”.

The preliminary screening criteria for supplier selection that is qualified and capable is to survey the production capacity and quality assessment of the supplier. This has criteria and survey supplier information, covering from Senior Management policies, Organisational structure, financial status, reliability, production facilitation tools, Technology and Quality management.

The preliminary screening criteria will help eliminate insufficient qualified suppliers, with only the list of qualified suppliers remaining. In the final step, the product and scope specifications are clearly defined and considered according to the criteria of each organisation.

Turban (1988) suggests that an alternative supplier should be chosen after the selection criteria have been established. This will digest the unqualified criteria for supplier selection. This can be done by eliminating the incomplete scope from the supplier, helping in the reduction of the number of suppliers who don’t qualify.

3.4.2 Decision criteria for fabrication pipeline supplier for gas pipeline industry

The fabrication pipeline supplier decision process may vary depending on the environment and structure of each organisation. The fabrication pipeline supplier decision consists of the following steps:

1. Consider the factors that will be represented as criteria in evaluating to select the fabrication pipeline supplier for the gas pipeline industry.

2. Find the weight of importance for each factor used as a criterion that has a relationship in accordance with the objectives.

3. Defining the method of rating for each criterion, factor and the method for measuring the performance of each factor used as a criterion and the method for measuring overall performance.

4. Prioritise each supplier based on the criteria.

3.5 Data collection

The data collection for the selection of a fabrication pipeline supplier for the gas pipeline industry will be carried out from the details of the book, related research, including some information from interviews with experts in the company's Procurement department, Operation and Plants Production department, Project Executive department and company functional expertise, case studies and other companies associated.

3.5.1 Consideration of factors used as the main criteria in the hierarchy model level 2

It is clearly explained that the supplier selection problem is a multi-criteria decision problem which consists of quantitative and qualitative criteria (Cengiz, 2017). The decision-making factor for the fabrication pipeline supplier depends on each department involved in the new pipeline project in the case study company. Initially, critical criteria are gathered from a literature review of previous studies based on Dickson's criteria in 1966. After studying the data from Dickson (1966), supplier selection criteria including asking for opinions from expertise and considering the need for each factor and then analysing the factors that affect the decision to choose the fabrication pipeline supplier in the hierarchy model level 2 (major criteria) that affect each decision consist of Cost, Quality, Delivery, Financial Stability and Technical Capability. The criteria are selected base on the meeting with the expert in the case company.

Factor	Criteria	Definition
1	Cost	Price that is appropriate for the product quality, price is not too high or too low.
2	Quality	All properties of the product that meet the specified standards or able to respond to user satisfaction
3	Delivery	Delivery on time where the product not deliver too early or too late.
4	Financial Stability	The company show strong financial position and suitable for the market conditions.
5	Technical Capability	Meet with the company specified standard, safety and have technology to support.

Table 8: Selection criteria in the hierarchy model level 2

Apart from the criteria mentioned in a previous section, the sub-criteria are also selected depending on interviews with experts in the company's Procurement Department, Operation and Plants Production Department, Project Executive Department and company functional expertise.

Factor	Level 2	Minor Consideration
1	Cost	Price Affordable and Negotiable
		Payment Term
		Discount Available.
2	Quality	Pipe Fabrication Quality
		ISO Certification
		Response to quality problem
3	Delivery	Plan to Execute project on time
		Confirmation Date of Completion Date
4	Financial Stability	Total Revenue
		Banking History
5	Technical Capability	Design standard
		Experience in similar project with Pipe rack owner and cased company
		Ability to execute Heavy equipment & Tools
		Safety management

Table 9: Selection criteria in the hierarchy model level 2 and 3

3.6 Building Questionnaire for supplier selection

After the set of criteria is confirmed by experts, the questionnaire asking about criteria weight and performance evaluation is constructed. The questionnaire is separated into 2 main sections and designed to ask the respondents to compare a given pair of criteria following Saaty's rating scale (1-9), as follows:

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the goal
2	Weak or slight	
3	Moderate importance	The decision maker slightly prefer one factor to another
4	Moderate plus	
5	Strong importance	The decision maker strongly prefer one factor to another
6	Strong plus	
7	Very strong or demonstrated importance	The decision maker very strongly prefer one factor to another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one factor over another is of the highest possible order of affirmation

Figure 14: Definition Ranking in the questionnaire 1

3.7 Construct the pairwise by AHP

According to the existence of relationships among criteria, the structure of criteria is constructed based on the AHP approach to select a fabrication pipeline supplier, which can be developed as shown in Figure 18. All main criteria have an effect on the case company purchaser judgment when selecting a supplier.

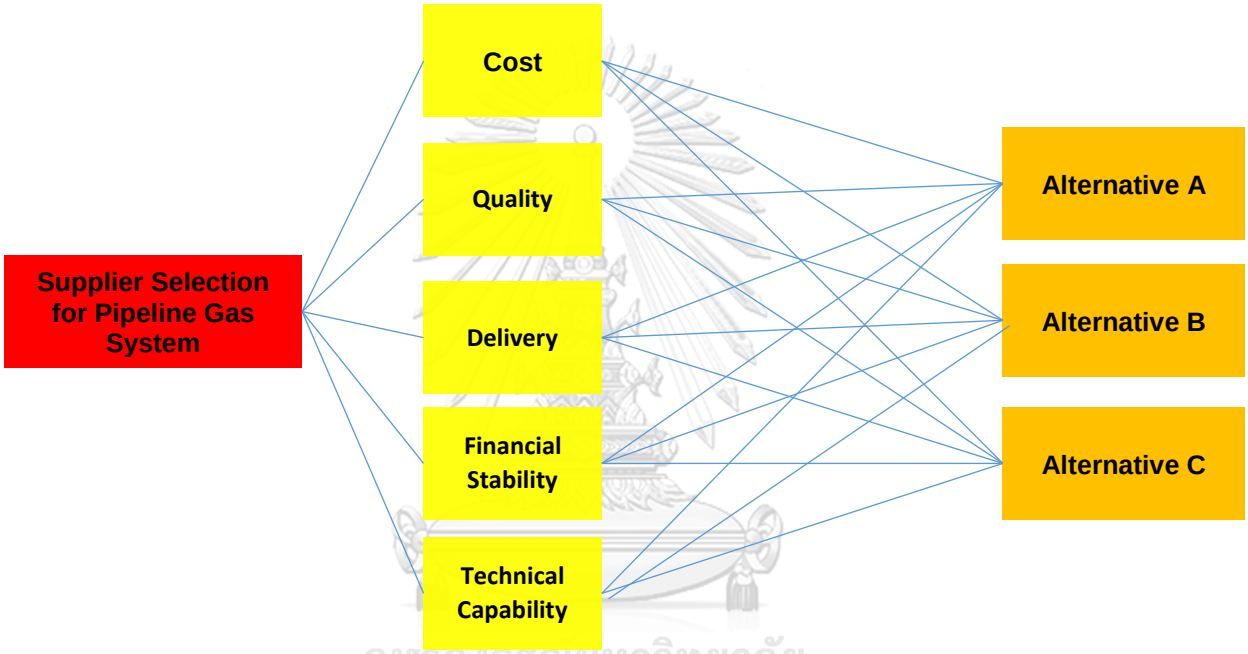


Figure 15: Case company selection criteria in pairwise

3.8 Questionnaire Data collection

After the analysis of the hierarchy structure is developed to prioritise the main factors and sub-criteria deciding on the fabrication pipeline supplier, the questionnaire will then be developed in accordance with the hierarchy structure in a form comparison as pairs. The results of the questionnaire development in the 3 parts of the questionnaire are as follows:

- Part 1 Preliminary information of respondents
- Part 2 Comparative information of various criteria according to the theory of hierarchical analysis process
- Part 3 Recommendations

For this section, a questionnaire is designed to ask the respondents to compare given pairs of criteria following Saaty's Rating scale, as in the table below. The questionnaire will be designed to match the selected factors. In this case, five criteria following Dickinson will be used for this study.

Factor	Most Important																Most Important	Alternative Supplier
Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
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	Financial Stability
Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
Financial Stability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability

Table 10: Example Table for rating score in hierarchy level 2 (Factor)

From the evaluation sample, the expert selects number 5 on the cost side, which means that the cost side is more important than the quality in the moderate level. From the table, it will show the relation between each factor and criteria. After completion, the questionnaire to assess the importance of all factors, the quantitative number of result can be entered into the Microsoft Excel program to continue analysis of the results.

The questionnaire will be similarly designed at an alternative level. However, this will be evaluated only by the Project Manager who has the highest responsibility level for this project.

Cost	Alternative Supplier	Most Important																Most Important	Alternative Supplier
1.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	RIC
2.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG
3.00	RIC	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG

Quality	Alternative Supplier	Most Important																Most Important	Alternative Supplier
1.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	RIC
2.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG
3.00	RIC	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG

Delivery	Alternative Supplier	Most Important																Most Important	Alternative Supplier
1.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	RIC
2.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG
3.00	RIC	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG

Financial Stability	Alternative Supplier	Most Important																	Most Important	Alternative Supplier
1.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	RIC
2.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG
3.00	RIC	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG

Technical Capability	Alternative Supplier	Most Important																	Most Important	Alternative Supplier
1.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	RIC
2.00	JPJ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG
3.00	RIC	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PEG

Table 11: Example Table for rating score in hierarchy level 4 (Alternative Supplier)

3.9 Develop the final matrix and find consistency

In the last part, the final matrix will be developed in order to find the weight.

	Cost	Quality	Delivery	Financial Stability	Technical Capability
Cost					
Quality					
Delivery					
Financial Stability					
Technical Capability					

Table 12: Example Table Matrix in hierarchy level 2

The quantitative number in the questionnaire will be transferred into the matrix in order to find the rank and prioritise. After pairwise comparisons have been completed, the consistency must be checked before calculating the important weights as well as alternative scores.

3.10 Compute the data from questionnaire to SpiceLogic

SpiceLogic AHP software (Analytic Hierarchy Process) is exactly the software that fulfills the objective of decision making. It is a modern intuitive wizard-based software that captures decision goals and preferences step by step from a wizard.

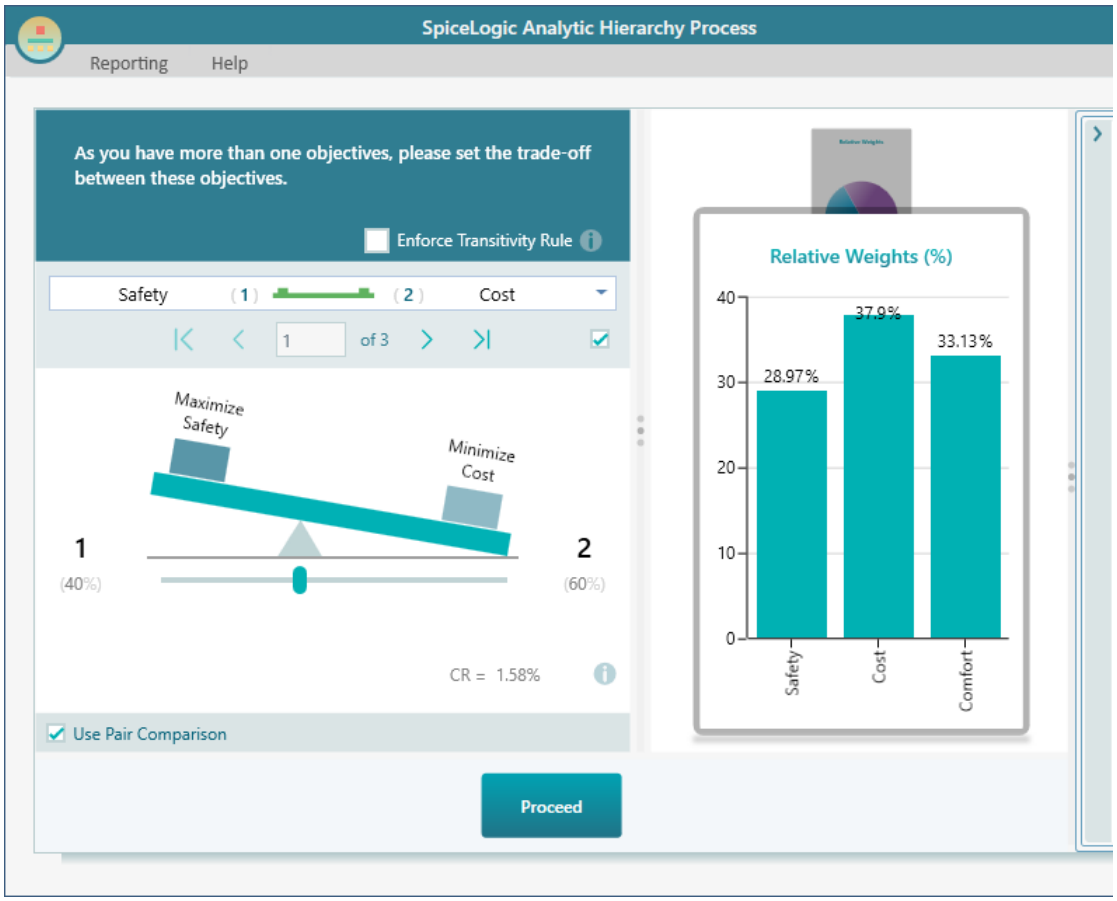


Figure 16: SpiceLogic Desktop

3.11 Consistency Ratio from Spice Logic

Consistency ratio is an important metric in the Analytic Hierarchy Process. That number describe how consistent in the pairwise comparisons. With the application result from the SpiceLogic AHP software, it shows the Consistency Ratio right beside the Pair comparison panel. According to Thomas L. Saaty, the consistency ratio should be less or equal to 10%. If the result of Consistency ratio goes beyond 10%, the software will indicate that using a Red bold colour.

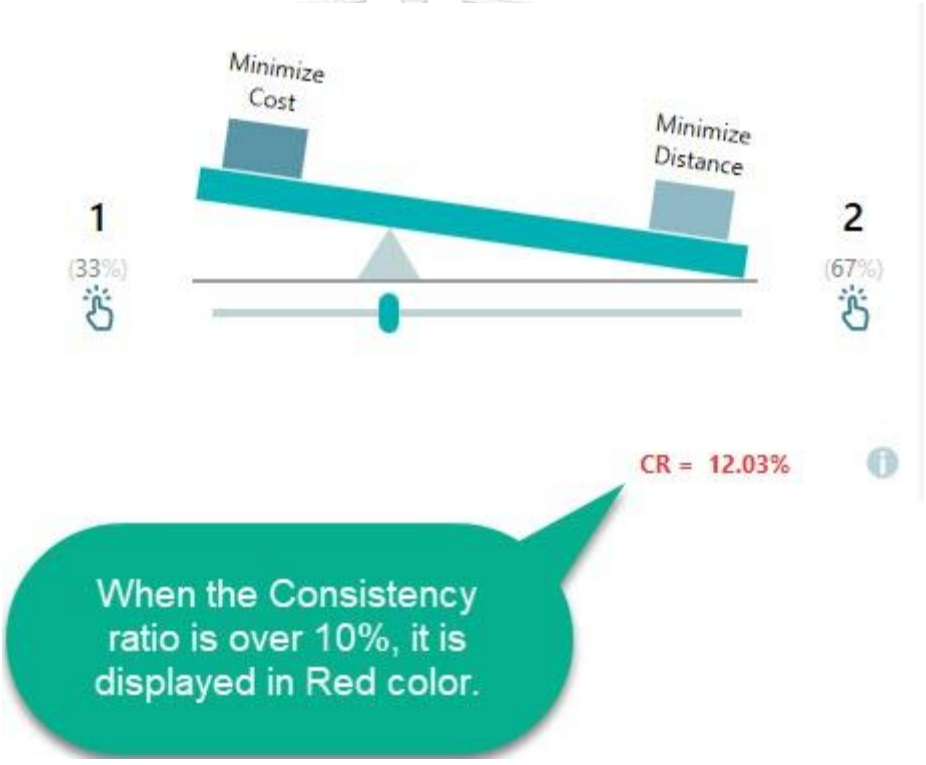


Figure 17: SpiceLogic show alert of CR Ratio

3.12 Result and Charts from SpiceLogic

The Options Analyser section displays the result and charts as shown below.

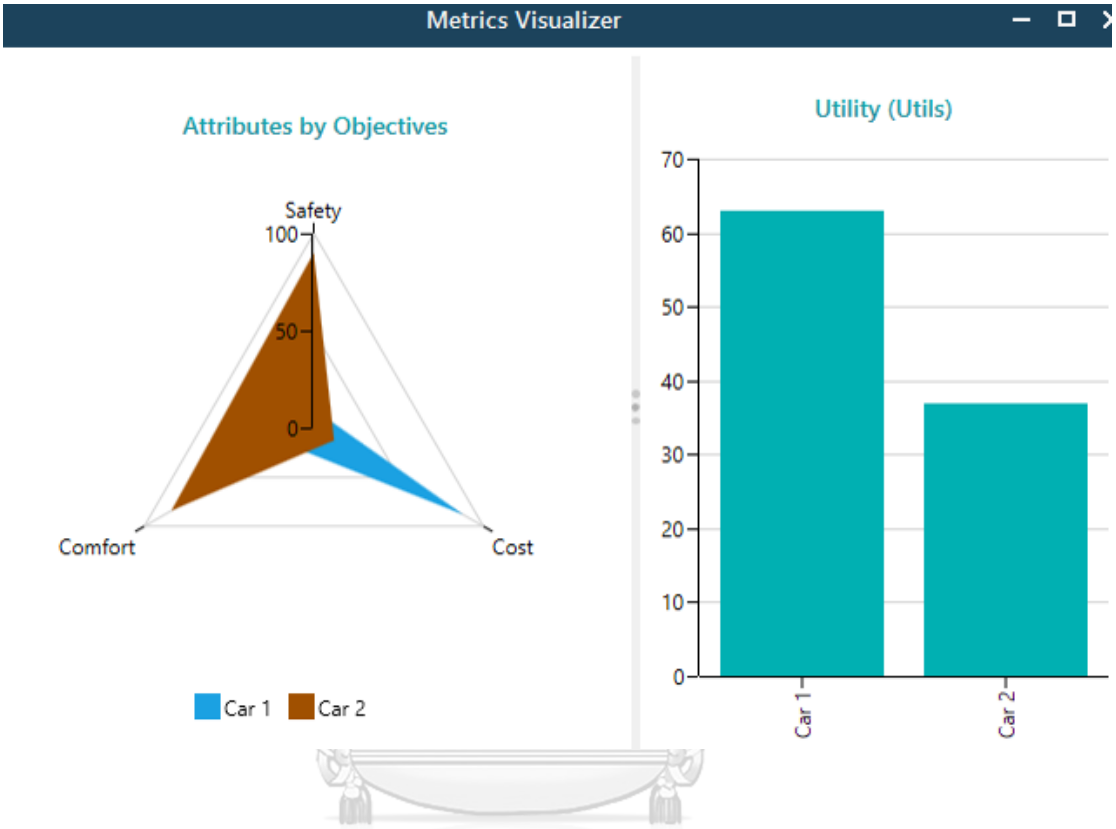


Figure 18: SpiceLogic shows result

3.13 Sensitivity Analysis from SpiceLogic

Sensitivity analysis is a important section of any decision analysis process. Without a proper sensitivity analysis, no decision can be describe to be a robust decision. SpiceLogic AHP software show all the variables based on the degree of sensitivity in the sensitivity panel.

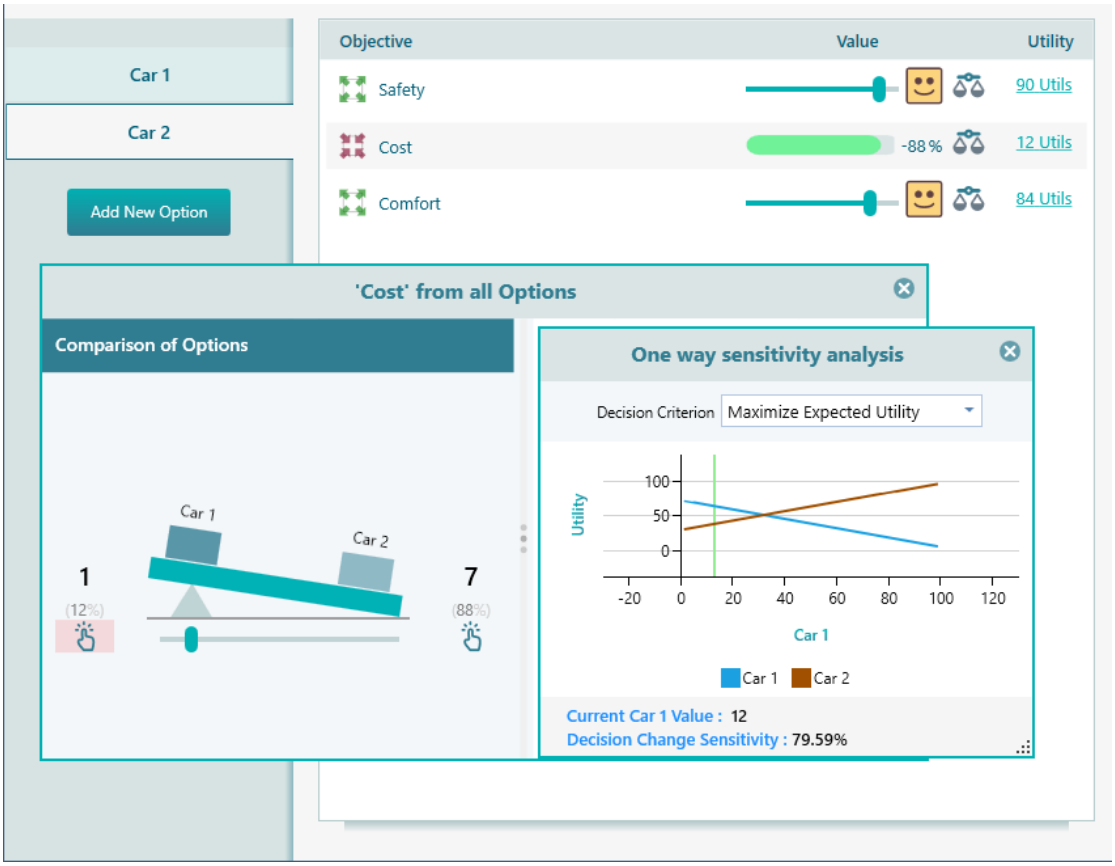


Figure 19: SpiceLogic Sensitivity Analysis

Chapter 4: Results

This chapter presents the results of data analysis obtained from the questionnaire survey. First, a summary of preliminary information from respondents is followed by criteria important weight and the results of evaluation.

4.1 Result from the Normal Practice from case company.

In practice, the case company uses the Simple Additive Weighting or linear averaging method to select its supplier. It is the most commonly used for supplier selection. In normal practice, the case company separate criteria into 2 part including Price offer part and Commercial and Technical score. The ratio is 50:50. The criteria that the case company selects in Commercial and Technical score are

- Business Management Score
- Responsiveness Score
- Product/Service Quality Score
- Design standard
- Experience in similar project with Piperack owner and Case Company
- Project management
- Ability to execute, Heavy equipment & Tools
- QC protocol and document control system
- Quality control & team communication
- Safety management and provision
- Competency of execution team
- Documentation & activity report

The score from Simple Additive Weighting are shown as below:

Company Name	JJJ	RRR	PPP
Price Perspective in THB			
Price Perspective in THB	3,318,190.00	4,000,000.00	5,578,985.50
Rank	1	2	3
Criteria from Commercial and Technical Perspective			
Business Management Score	5	4	4
Responsiveness Score	5	3	3
Product/Service Quality Score	4	4	4
Design standard	4	4	4
According to Tender, Scope	4	4	4
Experience in similar project with Piperack owner and LTH	3	5	3
Project management	4	4	4
Ability to execute, Heavy equipment & Tools	4	4	4
QC protocol and document control system	4	5	3
Quality control & team communication	4	5	3
Safety management and provision	4	4	4
Competency of execution team & Org strategy	5	4	4
Documentation & activity report	5	4	3
Total Score	55	54	47
Rank	1	2	3
Total Rank	**1**	**2**	**3**

Table 13: Normal Simple Addictive Score

As the result from this method, JJJ considered as the highest score. JJJ also provide the cheapest price compare to other. The price from JJJ, RRR and PPP are 3,318,190.00, 4,000,000.00 and 5,578,985.50, respectively. The drawback of this method is mainly focused on the quantitative criteria, which is easier to be measured. On the other hand, qualitative issues were not included.

Therefore, the process of AHP will be conducted to compare with Simple Additive Weighting in the next chapter.

4.2 Summary of preliminary information from respondents

The questionnaire was sent to management supervisors and workers involved in the selection of a fabrication pipeline supplier, as in the table below.

No.	Department	Title	Work Experience	Gas Manufacturing Experience
1	Procurement	Head of Procurement Thailand/Vietnam	22	10
2	Procurement	Procurement Manager	13	13
3	Procurement	Procurement Specialist	6	3
4	Project Executive	Head of Project Execution	20	12
5	Project Executive	Project Manager	25	6
6	Operation	Operation Manager	19	11

Table 14: Preliminary information of Respondents

The results of the questionnaire involve 6 experts from the case company who have experience with Pipeline Systems. The data can be displayed from the analysis process using the hierarchical analysis process and using calculations based on pair-wise comparison. The results can be based on a hierarchy of objectives, factors, and options for choosing fabrication pipeline suppliers, as follows:

1. Weighing the importance in each factor and sub-criteria of the objective that is the result of choosing the fabrication pipeline supplier

2. Rank the prioritised factors and sub-criteria under the objectives
3. Assessment results of alternatives through each factor

4.2.1 Weighing the importance in each factor and sub-criteria of the objective that is the result of choosing the fabrication pipeline supplier

Table 15 can be used to calculate weight, importance, and evaluation criteria by adjusting the "sum" of each column to equal. Refer to Table 16 resulting in Factor Ratio, then calculate the sum of each row and divide that sum by "number" of the criteria used in the decision, resulting in the prioritisation shown in Table 17.

Factor	Cost	Quality	Delivery	Financial Stability	Technical Capability
Cost	1.00	1.00	0.33	3.00	0.33
Quality	1.00	1.00	1.00	4.00	1.00
Delivery	3.00	1.00	1.00	5.00	2.00
Financial Stability	0.33	0.25	0.20	1.00	0.33
Technical Capability	3.00	1.00	0.50	3.00	1.00
Vertical Total Sum	8.33	4.25	3.03	16.00	4.67

Table 15: Convert Number from Raw data

Factor	Cost	Quality	Delivery	Financial Stability	Technical Capability
Cost	0.12	0.24	0.11	0.19	0.07
Quality	0.12	0.24	0.33	0.25	0.21
Delivery	0.36	0.24	0.33	0.31	0.43
Financial Stability	0.04	0.06	0.07	0.06	0.07
Technical Capability	0.36	0.24	0.16	0.19	0.21

Table 16: Factor Ratio from 1 person

After calculation of Ratio, the prioritisation can be calculated by the average of each column. The results are represented in Table 17.

Factor	Cost	Quality	Delivery	Financial Stability	Technical Capability	Prioritize
Cost	0.12	0.24	0.11	0.19	0.07	0.14
Quality	0.12	0.24	0.33	0.25	0.21	0.23
Delivery	0.36	0.24	0.33	0.31	0.43	0.33
Financial Stability	0.04	0.06	0.07	0.06	0.07	0.06
Technical Capability	0.36	0.24	0.16	0.19	0.21	0.23

Table 17: Priority from 1 person

Priority derived from the calculations is known as local priority, in which the sum of the priority factors must be equal to 1.

After pairwise comparisons have been completed, the consistency must be checked before calculating important weights as well as alternative scores. This can be judged by consistency ratio (CR), which is computed by the following equation:

$$CR = \frac{CI}{RI} \tag{2.2}$$

$$CI = \frac{\lambda_{max} - n}{n} \tag{2.3}$$

Where CR is consistency ratio

CI is consistency index

RI is random consistency index

λ_{max} is the largest Eigen value

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

The value of RI is related to the number of elements in the pairwise matrix (n) and will be used from Table 16. It should be noted that a consistency ratio lower than 0.10 means the results of comparison are consistent.

n	1	2	3	4	5	6	7	8	9	10
CI(Theory)	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Table 18: The value of Random Consistency Index Source: Golden and Wang (1990)

Factor	Cost	Quality	Delivery	Financial Stability	Technical Capability	Prioritize	λmax = Vertical Sum x Prioritize
Cost	0.12	0.24	0.11	0.19	0.07	0.14	1.2
Quality	0.12	0.24	0.33	0.25	0.21	0.23	1.0
Delivery	0.36	0.24	0.33	0.31	0.43	0.33	1.0
Financial Stability	0.04	0.06	0.07	0.06	0.07	0.06	1.0
Technical Capability	0.36	0.24	0.16	0.19	0.21	0.23	1.1
Vertical Sum	8.3	4.3	3.0	16.0	4.7	**λmax**	**5.23**
						CI	**0.06**
						CR	**0.05**

Table 19: Ramda Max from 1 person

λ_{max} is the largest Eigen value, which is equal to 5.23 and will be used to calculate the consistency ration (CR). As a result, CR is equal to 0.05, which is lower than 0.1. This means that it is consistent.

4.2.2 Weighing the importance in each factor using SpiceLogic Program

After collecting raw data from the questionnaire, all the raw data was input into SpiceLogic Program, resulting in the below table. The program automatically calculates for Consistency Ratio as a result of 0.05.

Cost	(1)		(1)	Quality
Cost	(1)		(3)	Delivery
Quality	(1)		(1)	Delivery
Cost	(3)		(1)	Financial Stability
Quality	(4)		(1)	Financial Stability
Delivery	(5)		(1)	Financial Stability
Cost	(1)		(3)	Technical Capability
Quality	(1)		(1)	Technical Capability
Delivery	(2)		(1)	Technical Capability
Financial Stability	(1)		(3)	Technical Capability

* Consistency Ratio calculated as 5.54%

Figure 20: Result of CR from SpiceLogic from Procurement Manager

Not only CR that was automatically calculated, the results of Factor are also provided.

Option Name	Utility
Cost	14Utils
Quality	23Utils
Delivery	33Utils
Financial Stability	6Utils
Technical Capability	23Utils

Figure 21: Priority (Calculated by SpiceLogic) from Procurement Manager

4.2.3 Comparing the results between Excel and SpiceLogic

Both programs, including Excel and SpiceLogic, used the same raw data from the questionnaire provided to the experts in the case study company. Significantly, the results of two program methods showed the same result.

Factor	Procurement Manager		Priority
	Excel	SpiceLogic	
Cost	0.14	0.14	4.00
Quality	0.23	0.23	2.00
Delivery	0.33	0.33	1.00
Financial Stability	0.06	0.06	5.00
Technical Capability	0.23	0.23	2.00
CR	0.053	0.055	

Table 20: Comparing the result between Excel and SpiceLogic

Therefore, other remaining respondent will be used SpiceLogic to identify the priority ranking and CR Ratio.

Cost	(1)		(7)	Quality
Cost	(2)		(1)	Delivery
Quality	(7)		(1)	Delivery
Cost	(1)		(2)	Financial Stability
Quality	(6)		(1)	Financial Stability
Delivery	(1)		(6)	Financial Stability
Cost	(1)		(7)	Technical Capability
Quality	(1)		(2)	Technical Capability
Delivery	(1)		(7)	Technical Capability
Financial Stability	(1)		(4)	Technical Capability

* Consistency Ratio calculated as 6.79%

Figure 22 : Result of CR from SpiceLogic from Head of Procurement

Option Name	Utility
Cost	6Utils
Quality	37Utils
Delivery	4Utils
Financial Stability	12Utils
Technical Capability	41Utils

Figure 23 : Priority (Calculated by SpiceLogic) from Head of Procurement

Cost	(1)		(1)	Quality
Cost	(1)		(2)	Delivery
Quality	(3)		(1)	Delivery
Cost	(5)		(1)	Financial Stability
Quality	(7)		(1)	Financial Stability
Delivery	(2)		(1)	Financial Stability
Cost	(5)		(1)	Technical Capability
Quality	(4)		(1)	Technical Capability
Delivery	(2)		(1)	Technical Capability
Financial Stability	(1)		(1)	Technical Capability

* Consistency Ratio calculated as 6.09%

Figure 24 : Result of CR from SpiceLogic from Project Manager

Option Name	Utility
Cost	28Utils
Quality	37Utils
Delivery	20Utils
Financial Stability	7Utils
Technical Capability	8Utils

Figure 25 : Priority (Calculated by SpiceLogic) from Project Manager

Cost	(1)		(9)	Quality
Cost	(1)		(3)	Delivery
Quality	(3)		(1)	Delivery
Cost	(2)		(1)	Financial Stability
Quality	(8)		(1)	Financial Stability
Delivery	(4)		(1)	Financial Stability
Cost	(1)		(9)	Technical Capability
Quality	(3)		(1)	Technical Capability
Delivery	(1)		(9)	Technical Capability
Financial Stability	(1)		(9)	Technical Capability

* Consistency Ratio calculated as 9.97%

Figure 26 : Result of CR from SpiceLogic from Plants and Operation Manager

Option Name	Utility
Cost	5Utils
Quality	43Utils
Delivery	11Utils
Financial Stability	4Utils
Technical Capability	38Utils

Figure 27 : Priority (Calculated by SpiceLogic) from Plants and Operation Manager

Cost	(1)		(5)	Quality
Cost	(1)		(2)	Delivery
Quality	(3)		(1)	Delivery
Cost	(2)		(1)	Financial Stability
Quality	(5)		(1)	Financial Stability
Delivery	(4)		(1)	Financial Stability
Cost	(1)		(3)	Technical Capability
Quality	(1)		(1)	Technical Capability
Delivery	(1)		(4)	Technical Capability
Financial Stability	(1)		(4)	Technical Capability

* Consistency Ratio calculated as 5.44%

Figure 28 : Result of CR from SpiceLogic from Procurement Specialist

Option Name	Utility
Cost	11Utils
Quality	36Utils
Delivery	14Utils
Financial Stability	6Utils
Technical Capability	33Utils

Figure 29: Priority (Calculated by SpiceLogic) from Procurement Specialist

Cost	(1)		(3)	Quality
Cost	(1)		(2)	Delivery
Quality	(5)		(1)	Delivery
Cost	(1)		(2)	Financial Stability
Quality	(8)		(1)	Financial Stability
Delivery	(3)		(1)	Financial Stability
Cost	(1)		(7)	Technical Capability
Quality	(1)		(1)	Technical Capability
Delivery	(1)		(3)	Technical Capability
Financial Stability	(1)		(5)	Technical Capability

* Consistency Ratio calculated as 5.57%

Figure 30 : Result of CR from SpiceLogic from Project Owner

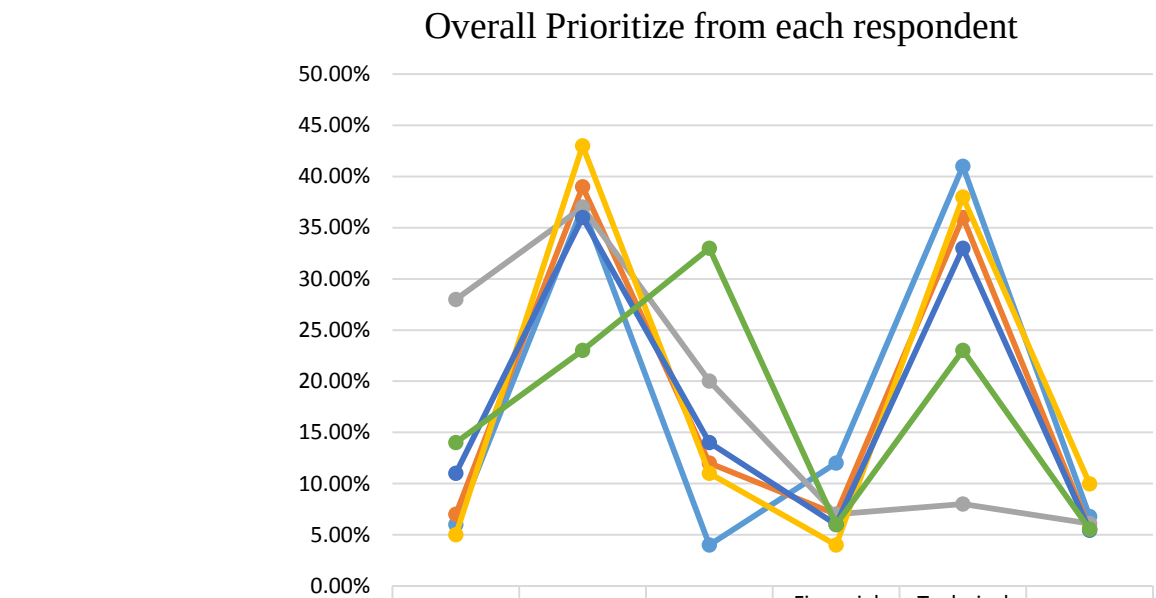
Option Name	Utility
Cost	7Utils
Quality	39Utils
Delivery	12Utils
Financial Stability	7Utils
Technical Capability	36Utils

Figure 31 : Priority (Calculated by SpiceLogic) from Project Owner

4.2.4 Overall Prioritisation and CR Ratio (Calculated result from SpiceLogic)

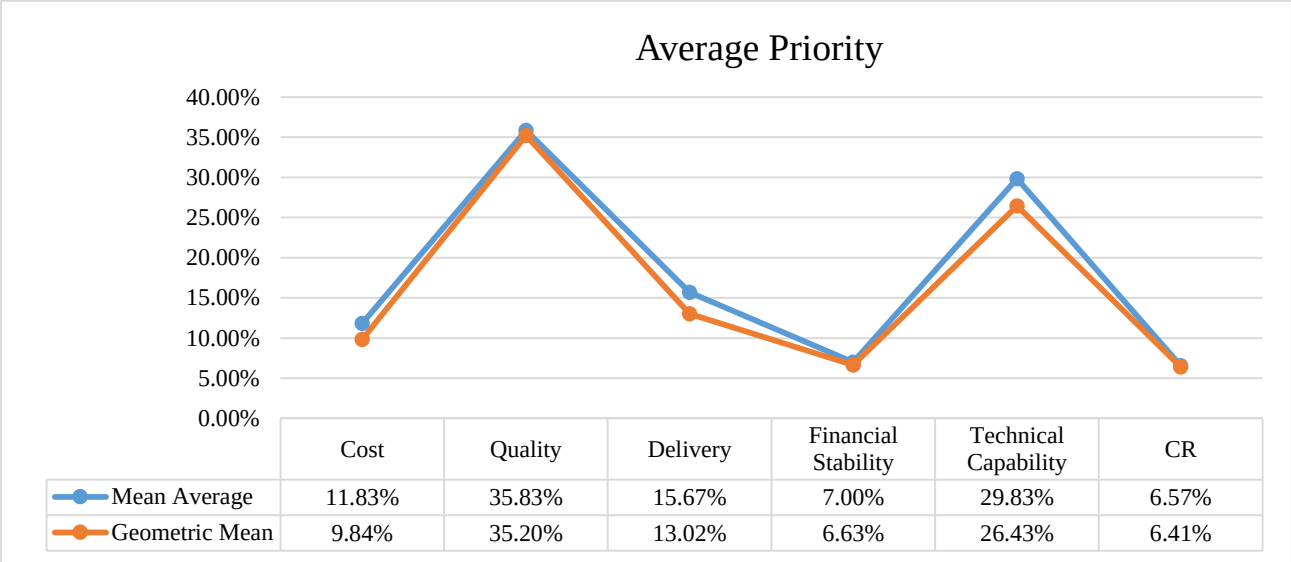
No	Title	Cost	Quality	Delivery	Financial Stability	Technical Capability	CR
1	Head of Procurement Thailand/Vietnam	6.00%	37.00%	4.00%	12.00%	41.00%	6.79%
2	Project Owner	7.0%	39.0%	12.0%	7.0%	36.0%	5.57%
3	Project Manager	28.00%	37.00%	20.00%	7.00%	8.00%	6.09%
4	Plants and Operation Manager	5.00%	43.00%	11.00%	4.00%	38.00%	9.97%
5	Procurement Specialist	11.00%	36.00%	14.00%	6.00%	33.00%	5.44%
6	Procurement Manager	14.00%	23.00%	33.00%	6.00%	23.00%	5.54%
	Mean Average	11.83%	35.83%	15.67%	7.00%	29.83%	6.57%
	Geometric Mean	9.84%	35.20%	13.02%	6.63%	26.43%	6.41%
	Overall Prioritize	4	1	3	5	2	

Table 21: Overall Prioritize and CR Ratio. (Calculated result from SpiceLogic)



	Cost	Quality	Delivery	Financial Stability	Technical Capability	CR
1 Head of Procurement Thailand/Vietnam	6.00%	37.00%	4.00%	12.00%	41.00%	6.79%
2 Project Owner	7.0%	39.0%	12.0%	7.0%	36.0%	5.57%
3 Project Manager	28.00%	37.00%	20.00%	7.00%	8.00%	6.09%
4 Plants and Operation Manager	5.00%	43.00%	11.00%	4.00%	38.00%	9.97%
5 Procurement Specialist	11.00%	36.00%	14.00%	6.00%	33.00%	5.44%
6 Procurement Manager	14.00%	23.00%	33.00%	6.00%	23.00%	5.54%

Figure 32 : Overall Prioritize from each respondent



	Cost	Quality	Delivery	Financial Stability	Technical Capability	CR
Mean Average	11.83%	35.83%	15.67%	7.00%	29.83%	6.57%
Geometric Mean	9.84%	35.20%	13.02%	6.63%	26.43%	6.41%

Figure 33 : Average Priority from every respondent

As result CR is equal to 0.06 which is lower than 0.1. This mean that the result from each expertise from cased company are consistence.

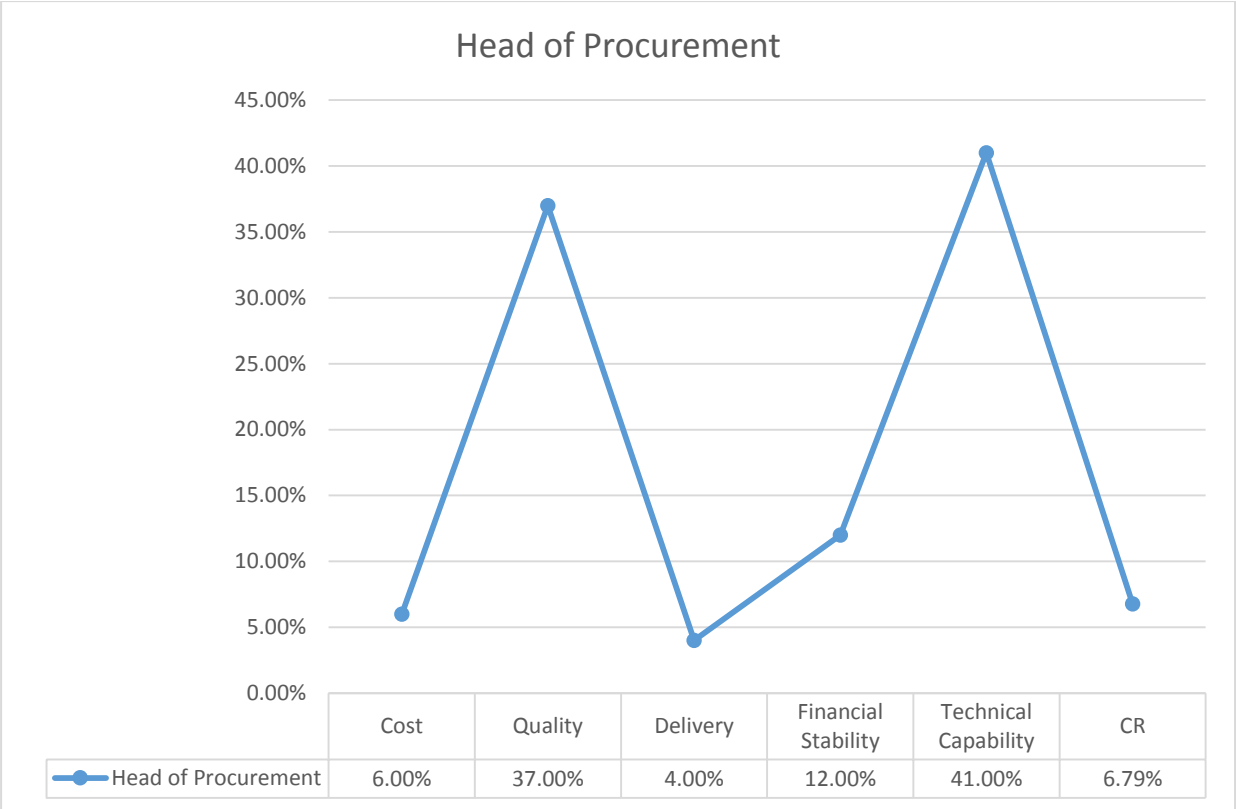


Figure 34 : Priority Ranking and CR ratio from Head of Procurement

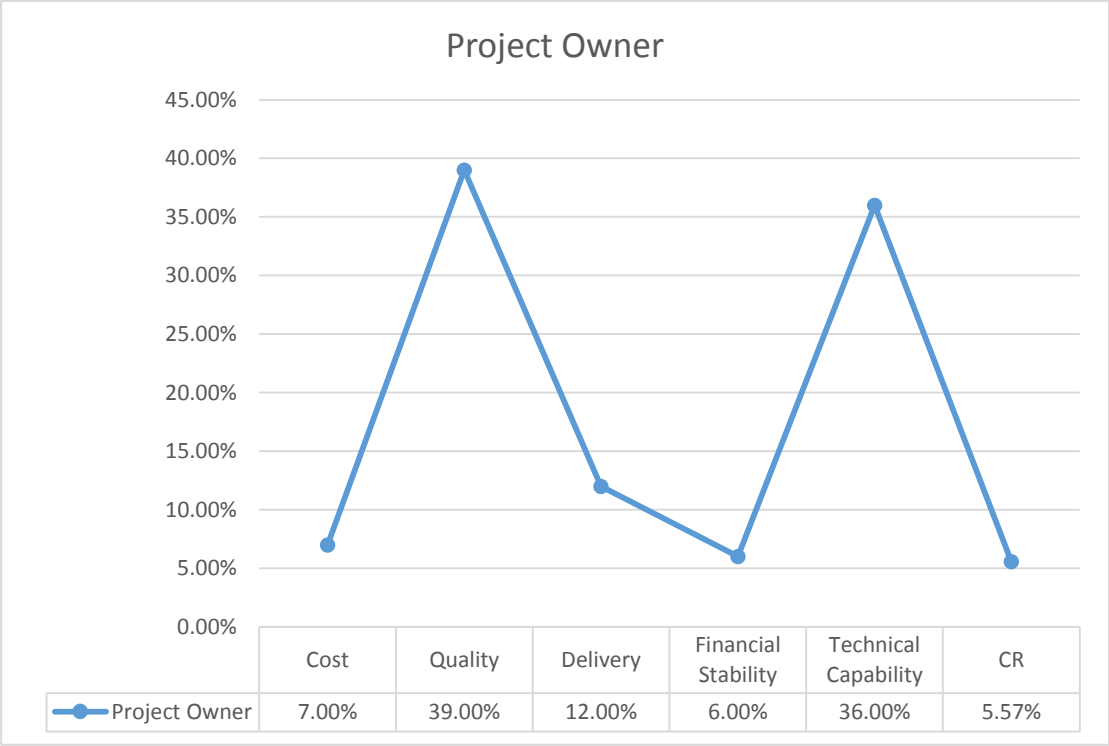


Figure 35 : Priority Ranking and CR ratio from Project Owner

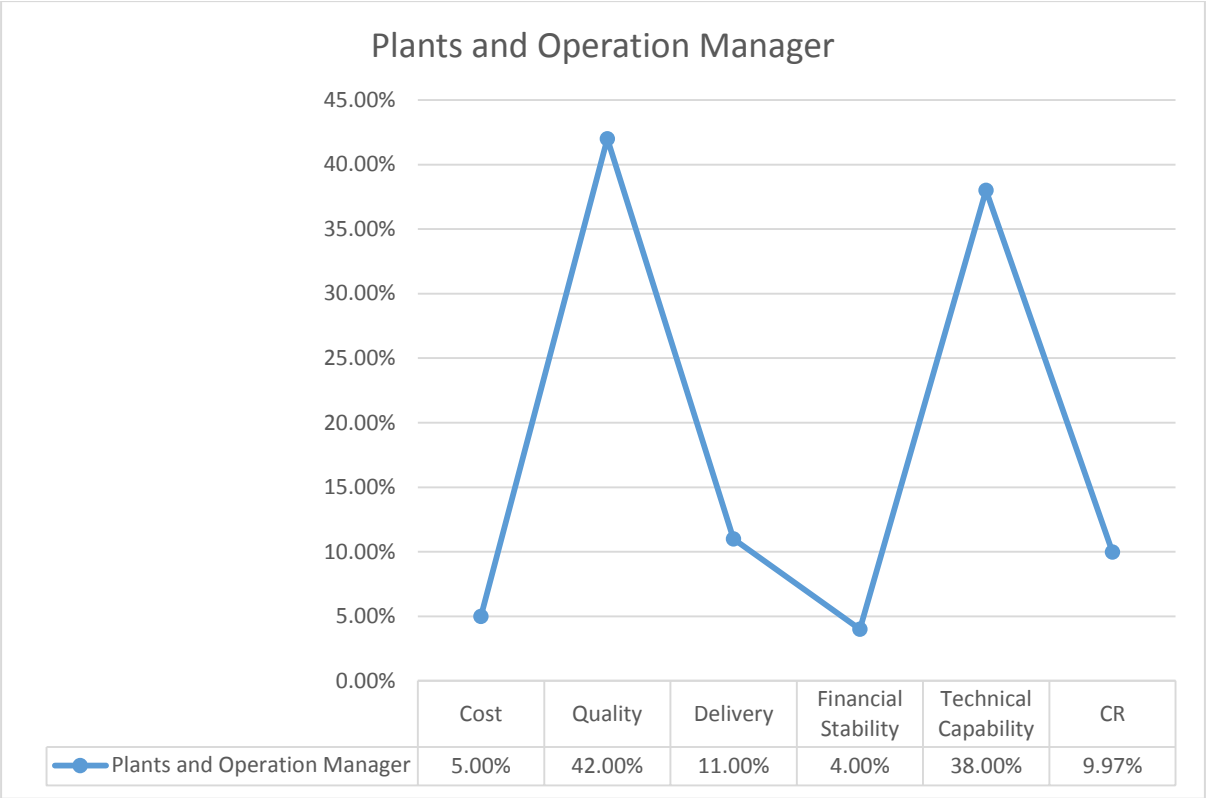


Figure 36 : Priority Ranking and CR ratio from Operation Manager

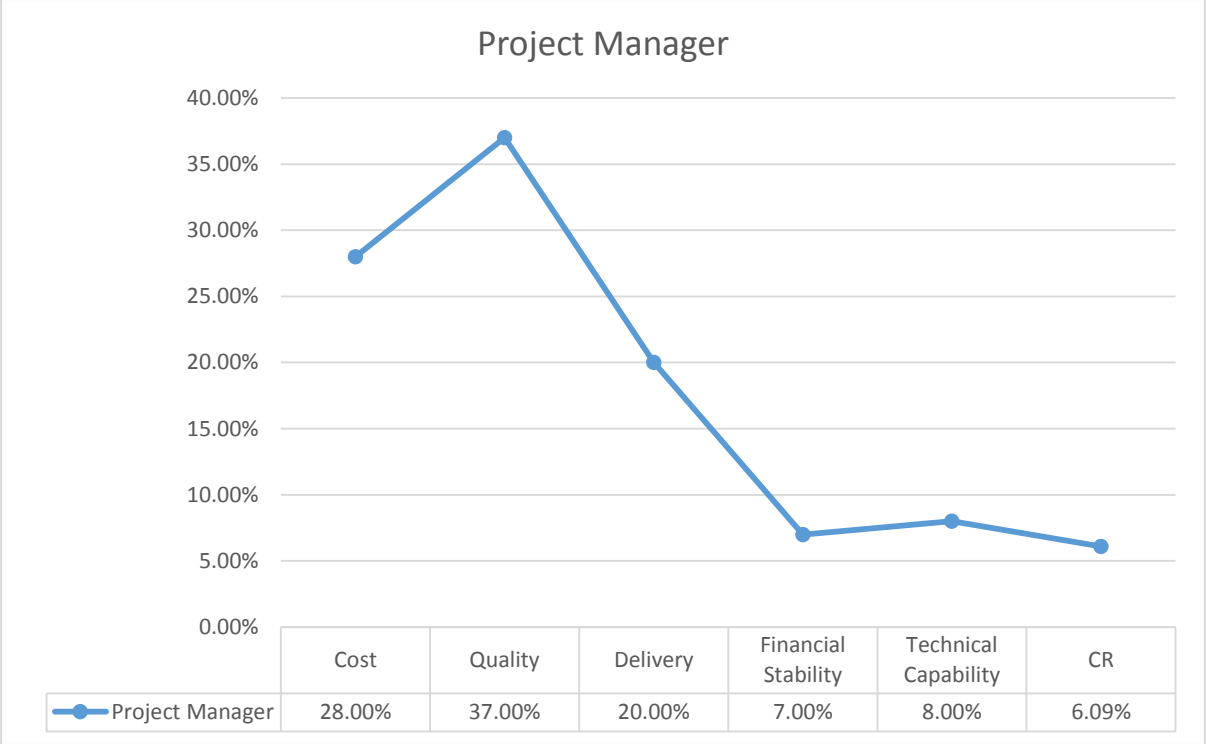


Figure 37 : Priority Ranking and CR ratio from Project Manager

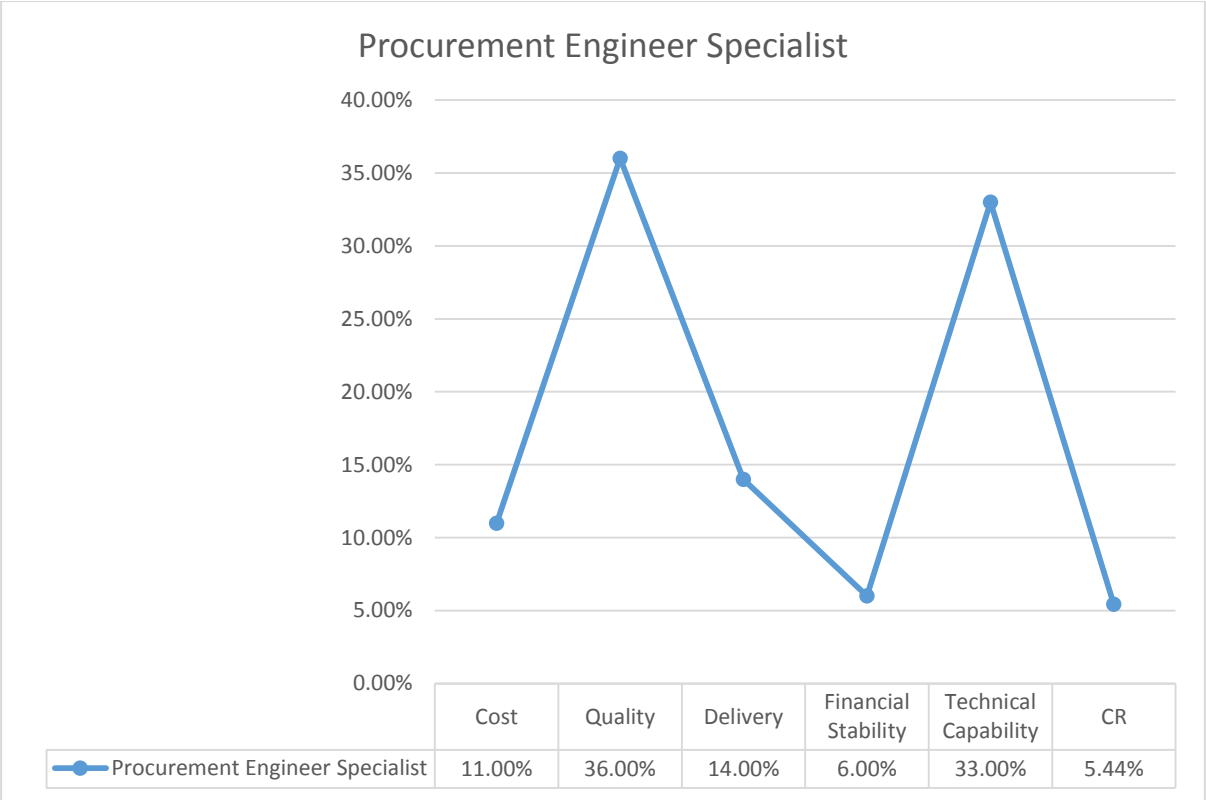


Figure 38 : Priority Ranking and CR ratio from Procurement Specialist

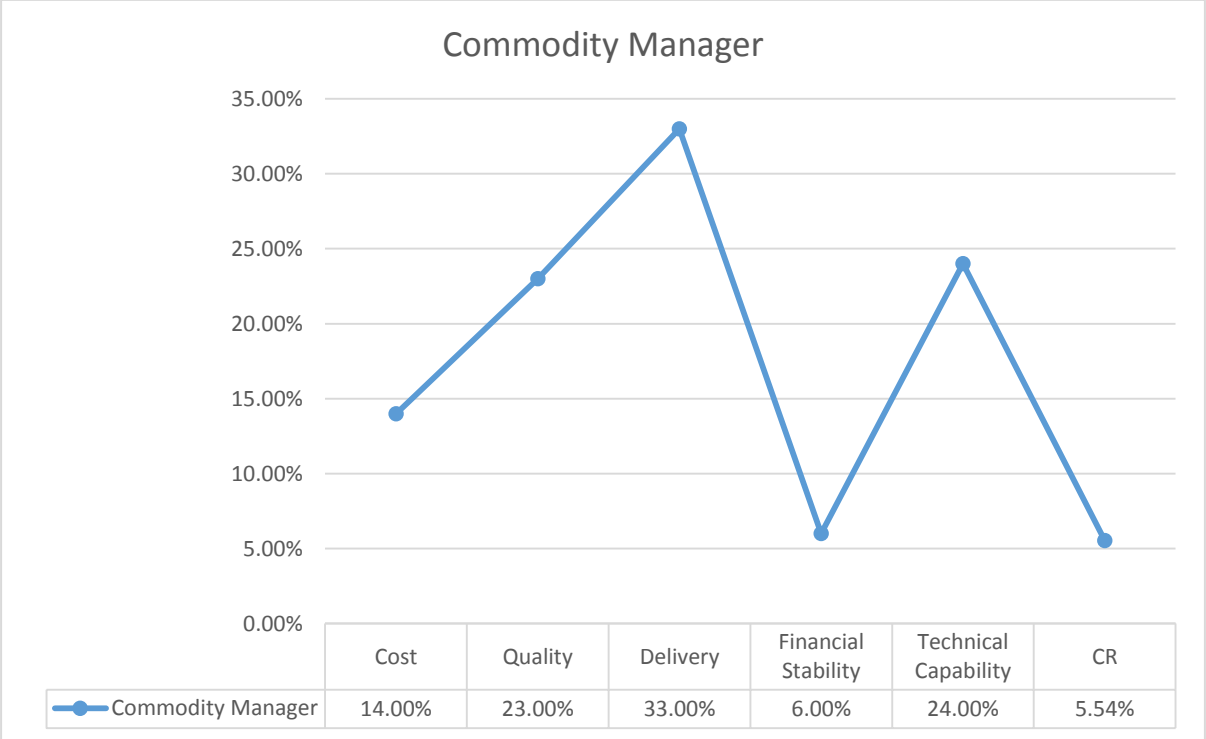


Figure 39 : Priority Ranking and CR ratio from Procurement Commodity Manger

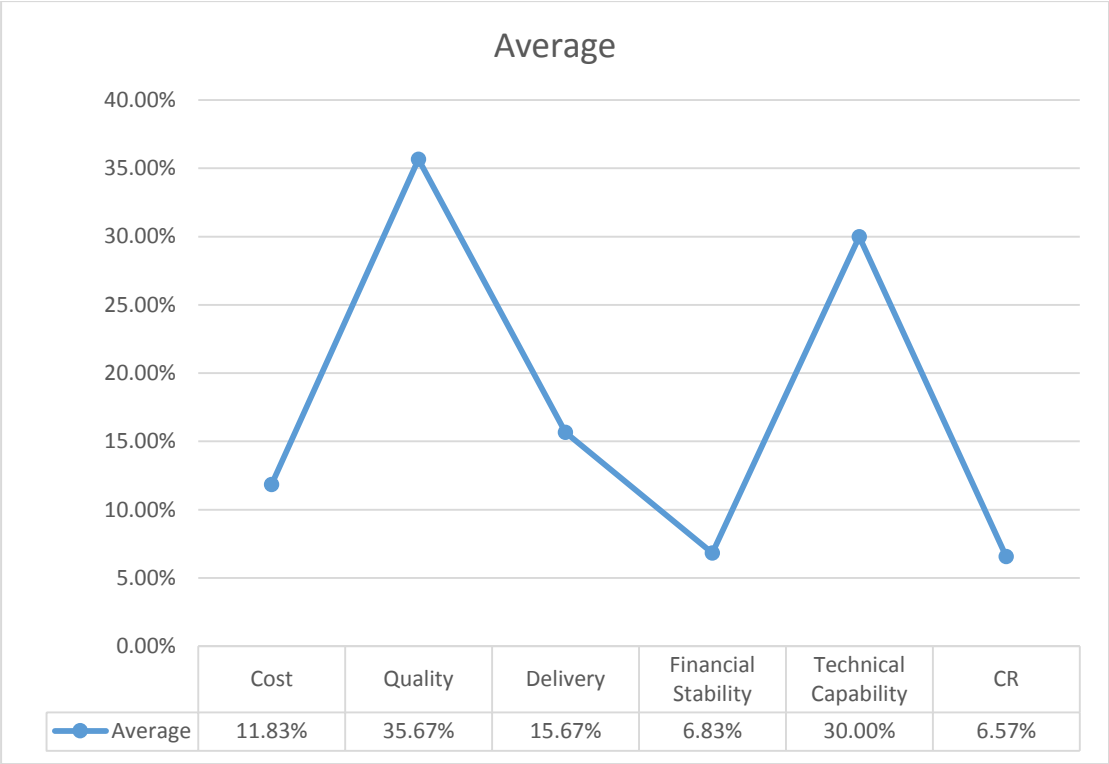


Figure 40 : Priority and CR average from all respondent

Priority Ranking

Figure 41 : Average Score Ranking

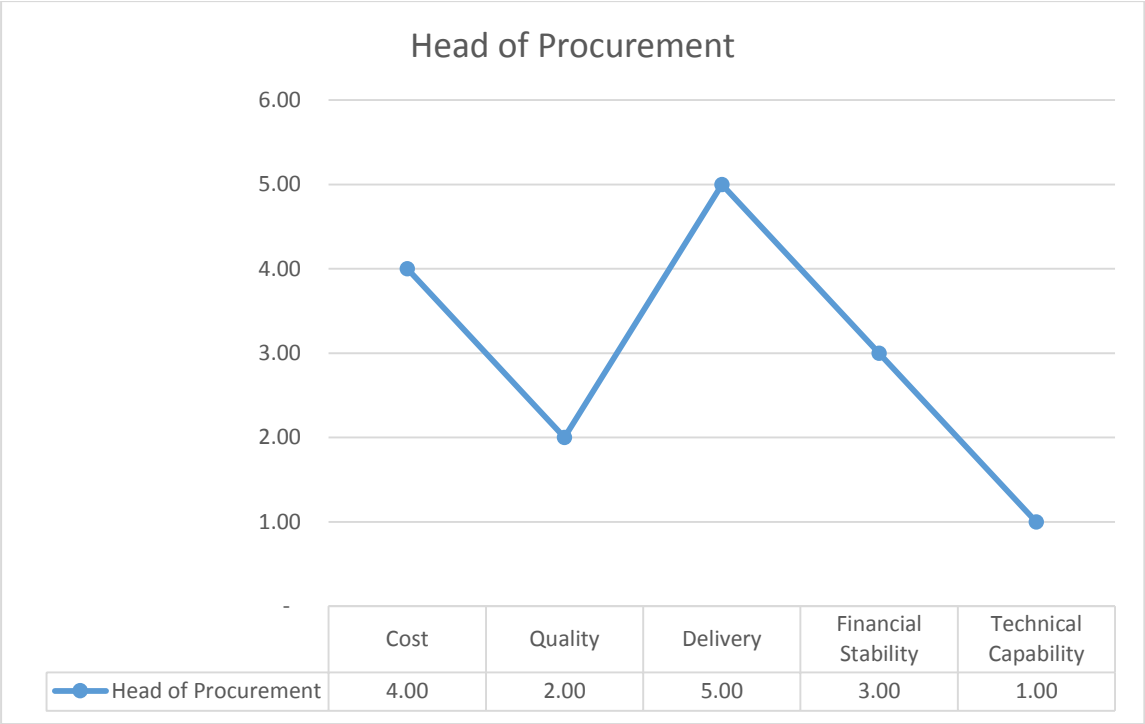


Figure 42 : Ranking by Head of Procurement

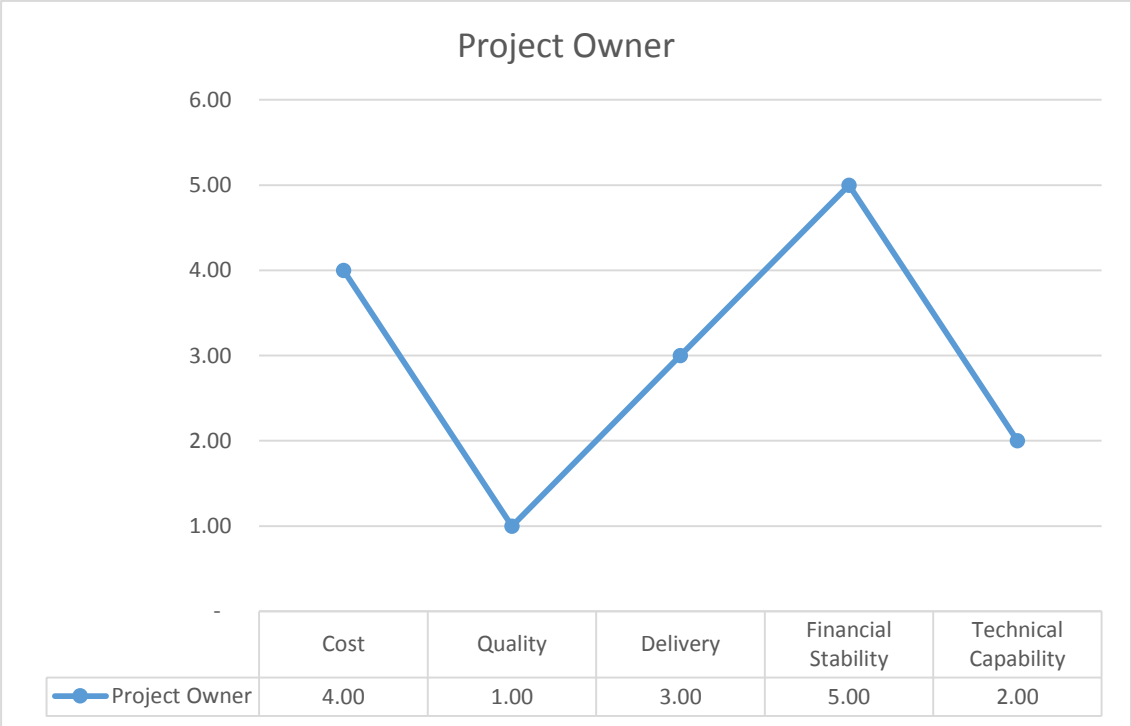


Figure 43 : Ranking by Project Owner

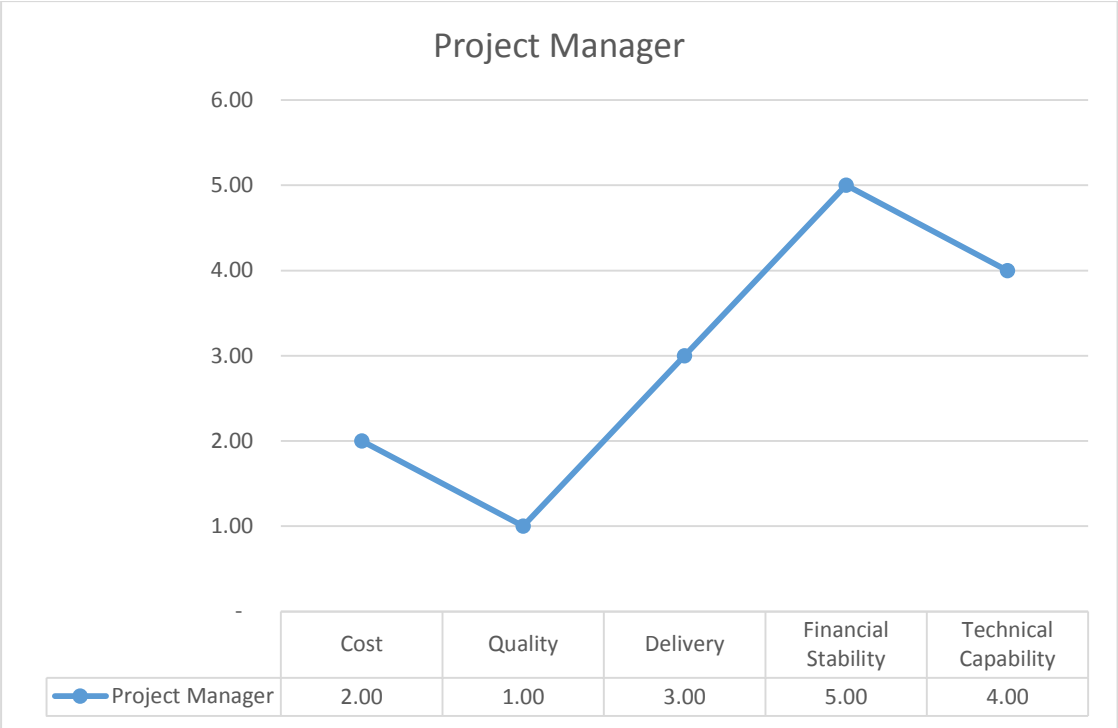


Figure 44 : Ranking by Project Manager

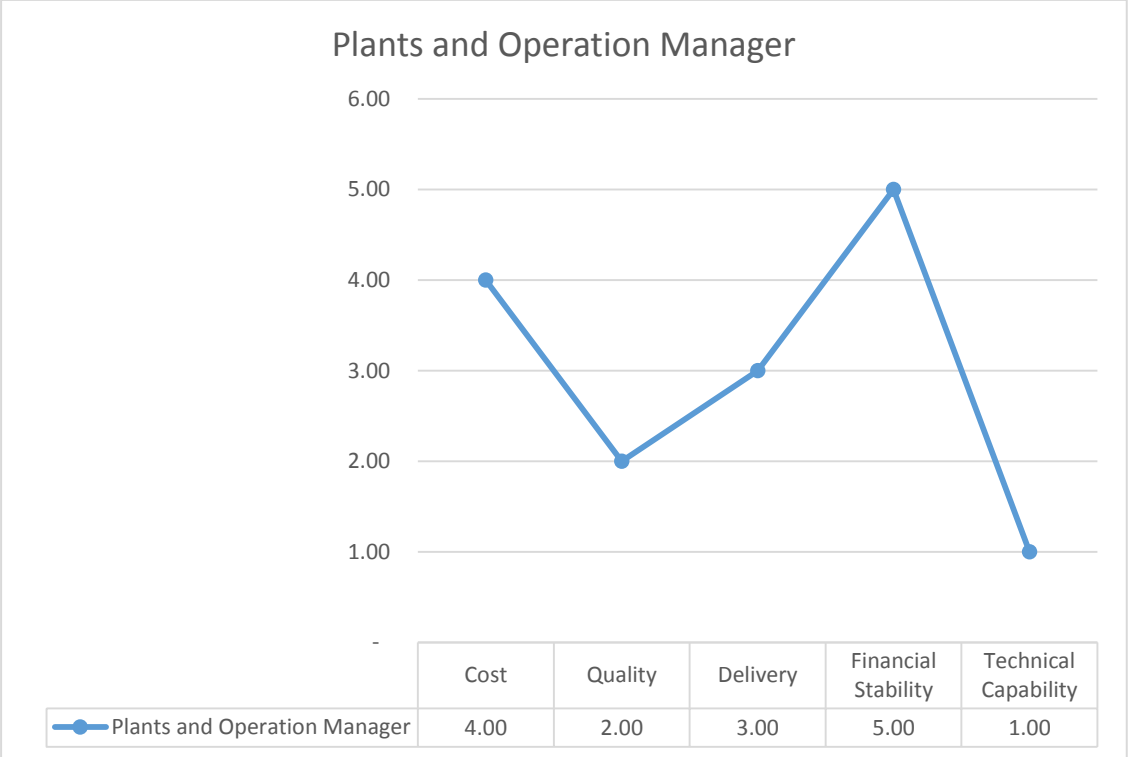


Figure 45 : Ranking by Operation Manager

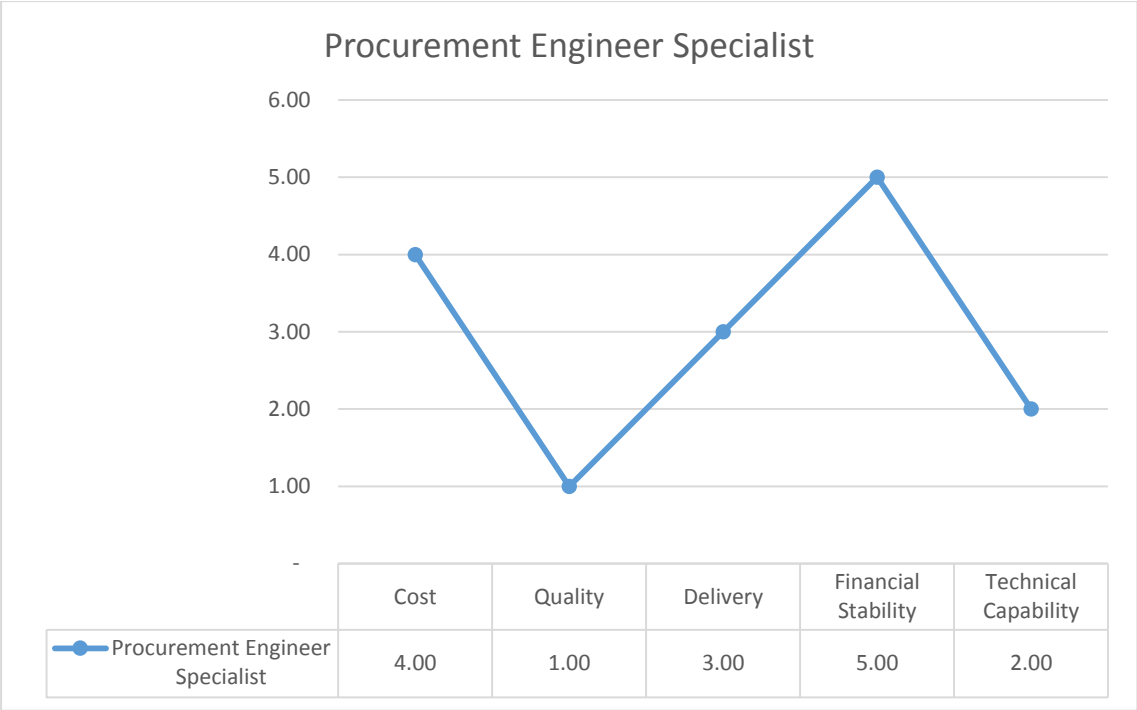


Figure 46 : Ranking by Procurement Specialist

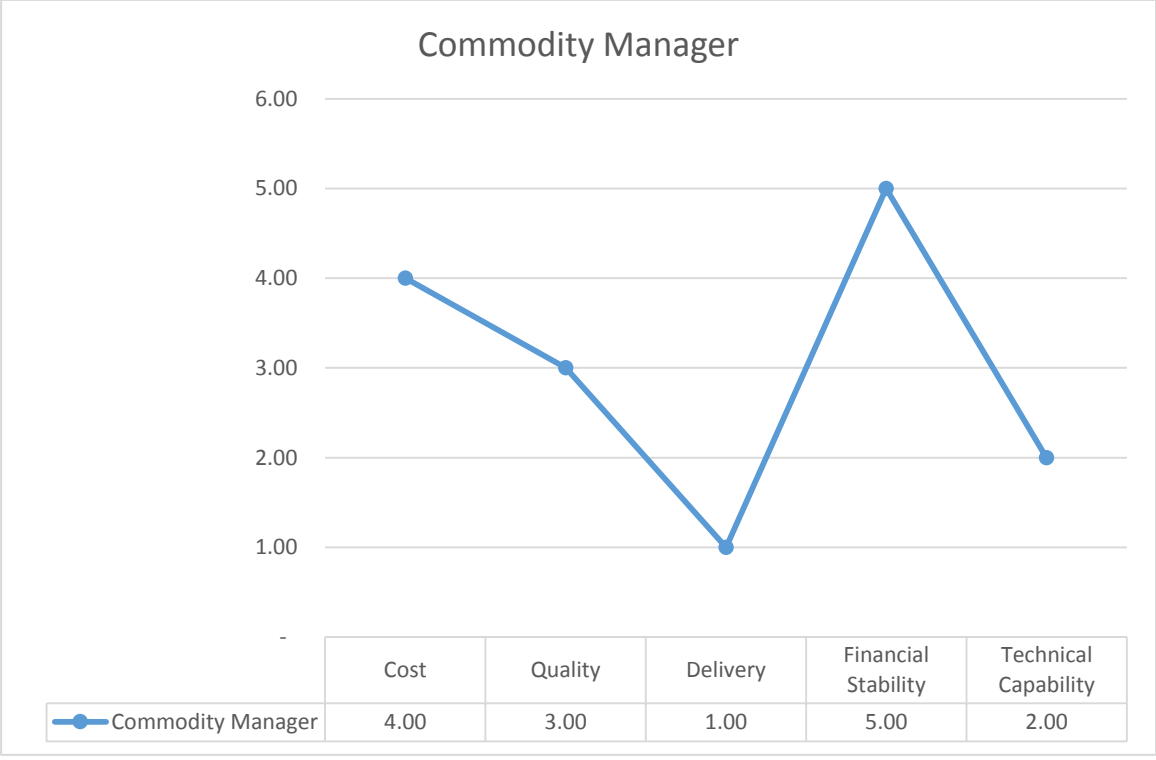


Figure 47 : Ranking by Procurement Manager

4.3 Sensitivity Analysis Result from SpiceLogic

The objective of sensitivity analysis is to study the trend of criteria change in pipe fabrication supplier when weight importance of factors change. The result will be discussed only decision change senility on quality. To support this idea, quality are consider as the most important criteria of this research as a result. Then, the changing in decision for each respondent will be observed when the quality decision was changed.

Head of Procurement Sensitivity Analysis

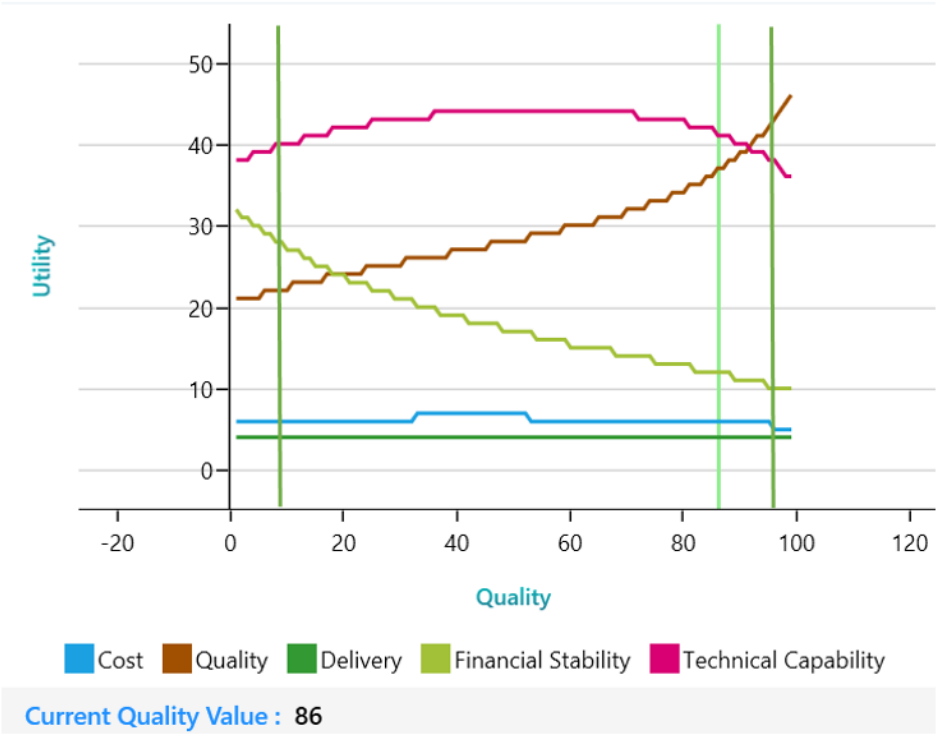


Figure 48 : Sensitivity Analysis from SpiceLogic for Head of Procurement

The sensitivity graph from Head of Procurement show that

At quality Value 10 : The ranking are Technical Capability > Financial Stability

Quality > Cost > Delivery

At quality Value 86 : The ranking are Technical Capability > Quality > Financial Stability > Cost > Delivery

At quality Value 99 : The ranking are Quality > Technical Capability > Financial Stability > Cost > Delivery

Project Owner Sensitivity Analysis

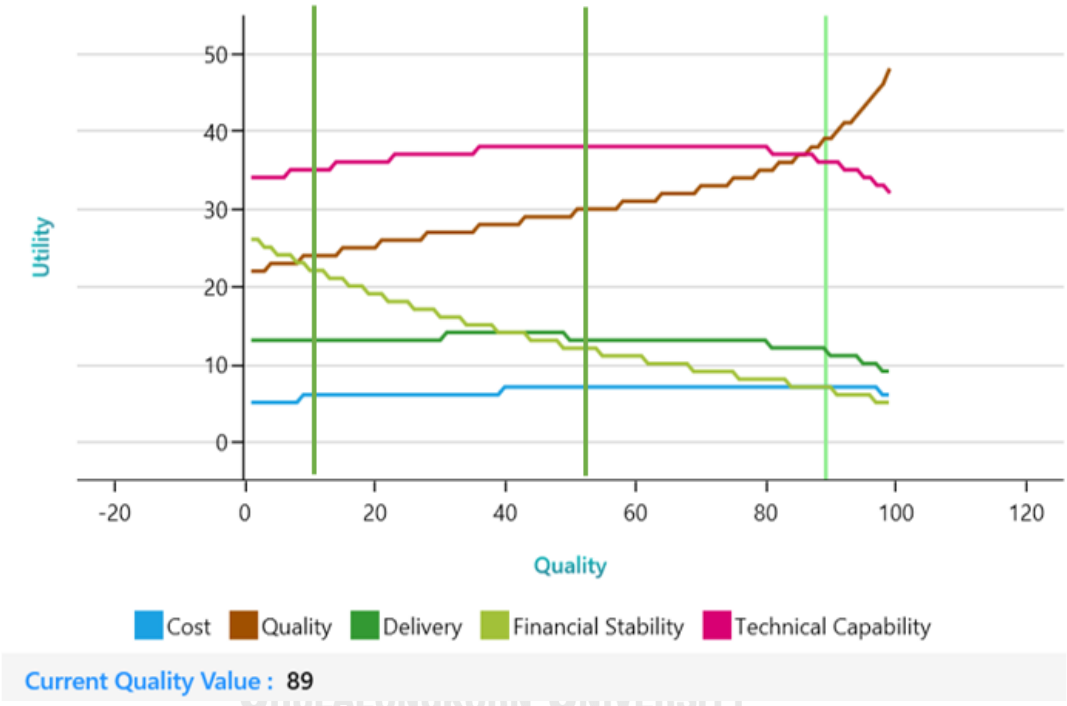


Figure 49 : Sensitivity Analysis from SpiceLogic for Project Owner

At quality Value 10 : The ranking are Technical Capability > Quality > Financial Stability > Delivery > Cost

At quality Value 50 : The ranking are Technical Capability > Quality > Delivery > Financial Stability > Cost

At quality Value 89 : The ranking are Quality > Technical Capability > Delivery > Financial Stability > Cost >

Project Manager Sensitivity Analysis

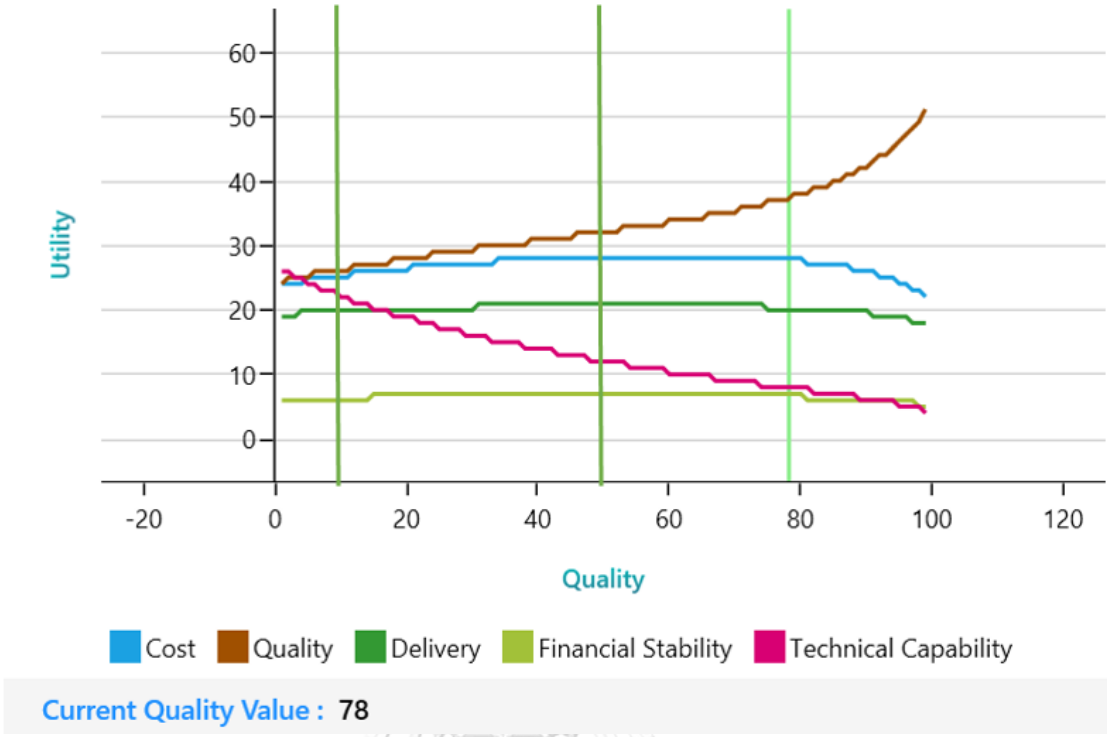


Figure 50 : Sensitivity Analysis from SpiceLogic for Project Manager

At quality Value 10 : The ranking are Quality > Cost > Technical Capability > Delivery > Financial Stability

At quality Value 50 : The ranking are Quality > Cost > Delivery > Technical Capability > Financial Stability

At quality Value 78 : The ranking are Quality > Cost > Delivery > Technical Capability > Financial Stability

Operation Manager Sensitivity Analysis

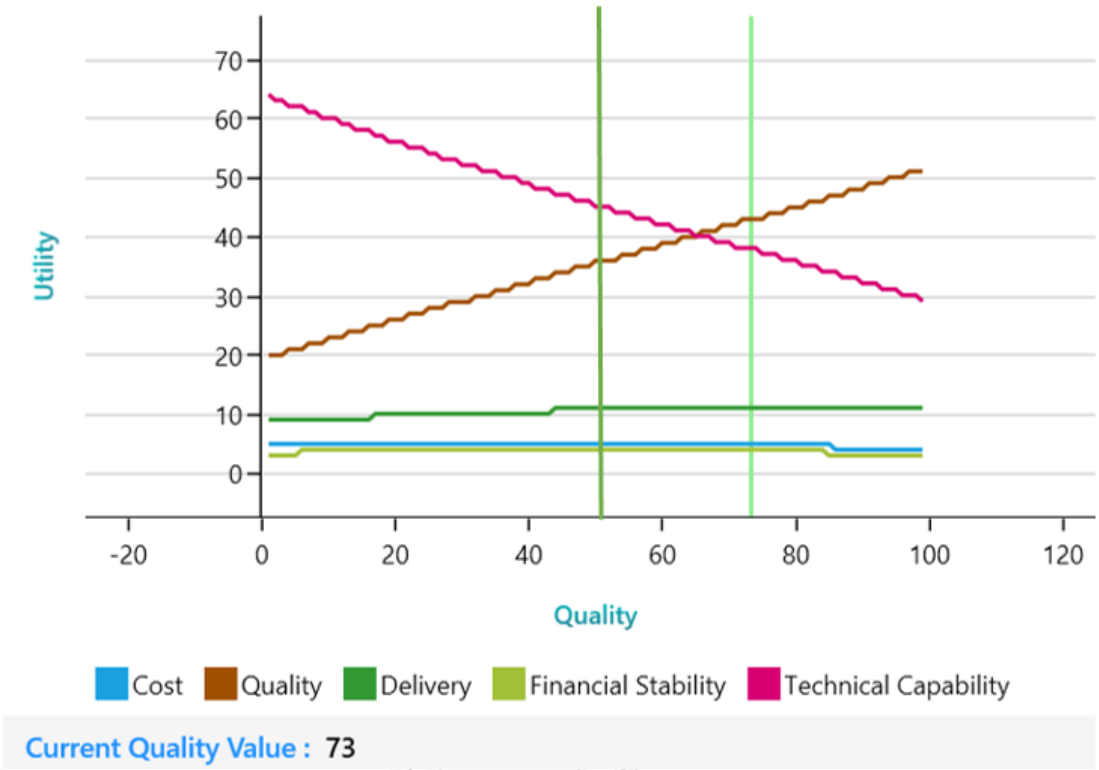


Figure 51 : Sensitivity Analysis from SpiceLogic for Operation Manager

At quality Value 50 : The ranking are Technical Capability > Quality > Delivery > Cost > Financial Stability

At quality Value 73 : The ranking are Quality > Technical Capability > Delivery > Cost > Financial Stability

Procurement Specialist Sensitivity Analysis

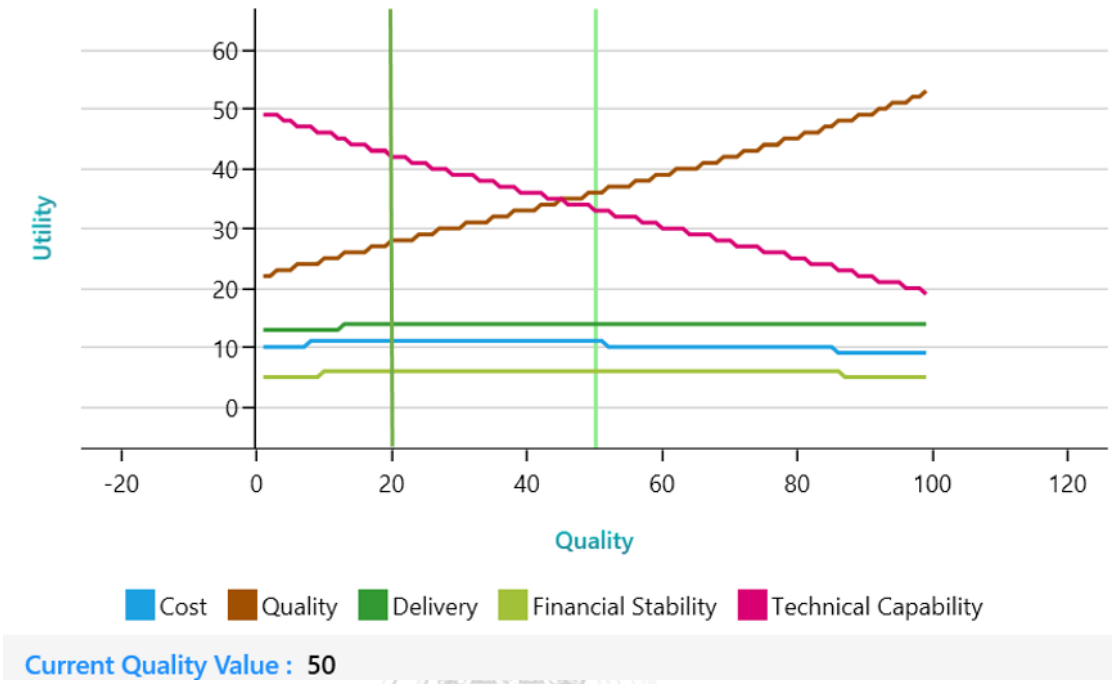


Figure 52 : Sensitivity Analysis from SpiceLogic for Procurement Specialist

At quality Value 20 : The ranking are Technical Capability > Quality > Delivery > Cost > Financial Stability

At quality Value 50 : The ranking are Quality > Technical Capability > Delivery > Cost > Financial Stability

Procurement Manager Sensitivity Analysis

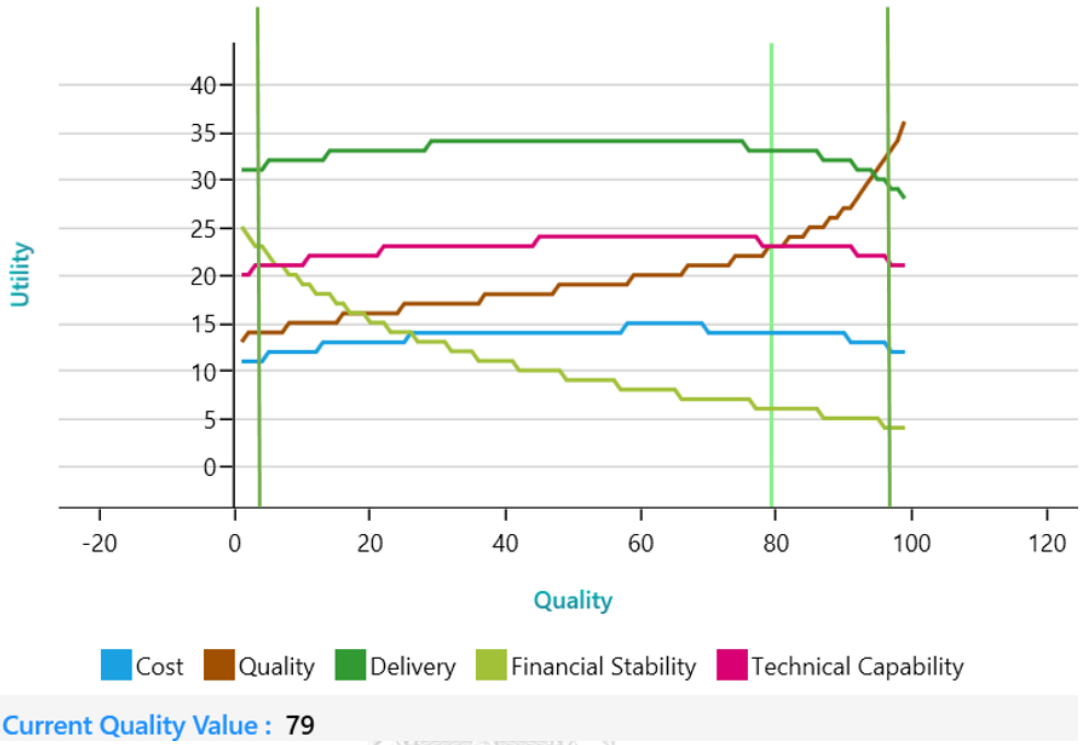


Figure 53 : Sensitivity Analysis from SpiceLogic for Procurement Manager

At quality Value 5 : The ranking are Delivery > Financial Stability > Technical Capability > Quality > Cost

At quality Value 79 : The ranking are Delivery > Technical Capability > Quality > Cost > Financial Stability

At quality Value 95 : The ranking are Quality > Delivery > Technical Capability > Cost > Financial Stability

4.4 Selecting an alternative Pipe Fabrication Supplier

There are 3 suppliers sourcing from the procurement department, including JPJ, RIC and PEG. All 3 of these suppliers are construction companies that specialise in pipeline fabrication.

Supplier Name JJJ detail

JJJ has been established since 17 January 2003 for the construction, modification and plant maintenance services for general industry & petrochemical plants. Since formation company has successfully managed numerous construction, plant shutdown & maintenance contracts. JJJ offer the best quality services to client with qualified and experienced management, supervision and trades personnel and the most suitable equipment.

Figure 54 : JJJ Quality Management System

JJJ are focus on continuous of quality management and receive ISO 9001 for the manufacturer of construction, metal fabrication and engineering service

Figure 55 : JJJ Site Visiting and their work

Due to the site visiting at JJJ's Fabrication shop, JJJ has qualified a skill of manpower and professional for the several service for example mechanicals, piping & pipelines, civil, turnaround and manpower resources

Supplier Name PPP detail

The second supplier that qualified for case company called PPP, this supplier have more than 20 year experience in oil and gas pipe fabrication and have a good relationship with the case company. The company's value proposition are safety where they focus on the concept of zero incidents, quality with conformity requirement

Figure 56 : PPP Site Visiting and their work

PPP have a large fabrication shop and warehouse , and Heavy Truck and equipment are available. The case company consider this Heavy Equipment as criteria. Therefore, PPP are quailed for the case company project.

Supplier Name RRR detail

RRR have established since 1997 by the group of professionally in quality and experience for Construction or Mechanical work such as Piping, for Industrial Plant. For more than 20 year service experience. RRR have continual improve by 50 person to 250 person in the organization with including Fabrication Shop with Overhead Crane 5-10 Ton. RRR have Certification Quality Standard Process of ISO9001:2008 and Certification by National Accreditation System of Thailand and Certificate Occupational Health and Safety Management System to Engineering, Procurement and Construction of Piping, Steel Structural and Pressure Vessel. With their core competency in quality control standard for pipeline fabrication and safety policy, RRR is consider to be the third alternative supplier for this research.

Figure 57 : RRR quality certificate

Because this is a case company special project, it requires technical knowledge. The project is under the responsibility of the project execution department in the case company. Therefore, the most senior authorised person who will select the supplier will be the Project Manager. By applying AHP, the Project Manager evaluates all the factors including Cost, Quality, Delivery, Financial Stability and Technical Capability in a Pairwise Matrix from each supplier. The result of the Project Manager's decision is shown in Table 22.

Supplier Name	Cost	Quality	Delivery	Financial Stability	Technical Capability	Overall	Selected Supplier
JJJ	0.07	0.21	0.07	0.02	0.08	0.44840	1
RRR	0.02	0.09	0.04	0.04	0.14	0.33631	2
PPP	0.01	0.04	0.02	0.01	0.04	0.12519	3

Table 22 : Overall Supplier Alternative Score

The result shows that JPJ, which was the selected supplier, is ranked as number 1 followed by RIC and PEG, respectively. The overall score for each supplier was 0.44, 0.33 and 0.12, respectively.

4.1.6 Construction after selecting the supplier

After JPJ was selected to fabricate and install at the case study customer's site, they performed professionally and aligned with the safety and environmental agreement. The work is on schedule. The quality of the pipe achieved the standard and gained case study satisfaction.

Figure 58 : Actual photos from the construction site

Chapter 5: Conclusion (Draft)

5.1 Conclusion

This study applied the hierarchical analysis process (AHP) to analyse the selection of the Pipe Fabrication Supplier. From the data gathered, the overall weight and factors that impacted this research can be concluded as below:

1. The overall results of factors that affected the alternative fabrication pipeline

Quality shows as the most important factor for this research with 0.35, followed by Technical Capability, Delivery, Cost and Financial Stability with 0.26, 0.13, 0.09 and 0.06, respectively. This means that the quality of welding joints, including quality management, will affect the decision. All 3 alternative supplier successfully managed numerous construction, plant shutdown & maintenance contracts with their best quality services to client with qualified and experienced management.

CR is equal to 0.06, which is lower than 0.1. This means that the results from each expert in the case company are consistent. Both programs, including Excel and SpiceLogic, used the same raw data from the questionnaire that was provided to the experts in the case study company. Significantly, the two program methods showed the same result.

2. Selected alternate supplier

The result shows that JJJ, which was the selected supplier, is ranked as number 1 followed by RRR and PPP, respectively. The overall score for each supplier is 0.44, 0.33 and 0.12, respectively.

5.2 Limitations

- SpiceLogic can only process one level with the Hierarchy
- Most respondents are the top management of the organisation – This is challenging in terms of communication due to their work loads.

5.3 Suggestions

- This method can be applied to real organisations.

In practice, the case company uses the Simple Additive Weighting or linear averaging method to select its supplier. It is the most commonly used for supplier selection. However, with its drawback to consider only quantitative detail. The case company can apply AHP process and set as a new standard procedure with quantitative and qualitative approach for supplier selection.

- The sub-criteria of AHP will impact different perspectives of decision making.

APPENDIX

Appendix A

Questionnaire comparing the criteria used to consider Pipeline Fabrication Supplier

Purpose

The purpose of this questionnaire is to fill in the consideration of the criteria that affect the decision to choose Pipeline Fabrication Supplier.

Statement for respondents

1. Please mark or highlight in the box of the message that is true and important from your knowledge as much as possible.
2. The research results will be used for the benefit of academic study purpose.

Details of the questionnaire

Part 1 Preliminary information of respondents

Part 2 Comparative data of various criteria according to the theory of hierarchical analysis process

Part 3 Recommendations

Part 1 General information of respondents

1. Gender □ Male □ Female
2. Age…….. years
3. Education level Undergraduate □ Bachelor's degree □ Master's degree □ Doctorate
4. Department…….....
5. Position ……...…….
6. Total Work experience…….…….year
7. Work experience in Gas Manufacturing Business……..year

Part 2 Comparative data of various criteria according to the theory of hierarchical analysis process

Criteria for comparison are compared in pairs. And set the comparative scale to the concentration level of importance with numbers 1 through 9. The meaning of the numbers shows the concentration level of importance as in Table 1.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the goal
2	Weak or slight	
3	Moderate importance	The decision maker slightly prefer one factor to another
4	Moderate plus	
5	Strong importance	The decision maker strongly prefer one factor to another
6	Strong plus	
7	Very strong or demonstrated importance	The decision maker very strongly prefer one factor to another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one factor over another is of the highest possible order of affirmation

Table 1. Comparative scales and definition

Factor Definition

Factor	Criteria	Definition
1	Cost	Price that is appropriate for the product quality, price is not too high or too low. This should consider Price Affordable and Negotiable, Payment Term and Discount Available.
2	Quality	All properties of the product that meet the specified standards or able to respond to user satisfaction including Pipe Fabrication Quality, ISO Certification and Response to quality problem.
3	Delivery	Delivery on time where the product not deliver too early or too late. This should focus on Plan to Execute project on time and Confirmation Date of Completion Date.
4	Financial Stability	The company show strong financial position and suitable for the market conditions.
5	Technical Capability	Meet with the company specified standard, safety and have technology to support. This should consider base on Design standard, Experience in similar project with Pipe rack owner and cased company, Ability to execute Heavy equipment & Tools, and Safety management

Question Set 1

Please mark or highlight in the box of the message that is true and important from your knowledge as much as possible for No 1 – 10

Example

No.	Factor	Most Important																Most Important	Alternative Supplier
1	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality

- If you select 7 in Cost Matrix. This mean that Cost is Very strong or demonstrated importance compare to Quality

No.	Factor	Most Important																Most Important	Alternative Supplier
1	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
2	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
3	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
4	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
5	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
6	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
7	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
8	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
9	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
10	Financial Stability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability

Question Set 2

Please mark or highlight in the box of the message that is true and important from your knowledge as much as possible for No 1 – 5

Example

	Cost	Alternative Supplier	Most Important								Most Important									Alternative Supplier
0	1.00	JPJ = JJJ	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	RIC = RRR
	2.00	JPJ = JJJ	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	PEG=PPP
	3.00	RIC = RRR	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	PEG=PPP

For Comparing about Cost of each supplier.

- Select 7 = This mean that we evaluate JPJ = JJJ Cost which is Very strong or demonstrated importance compare to Cost of RIC.
- Select 5 = This mean that we evaluate JPJ = JJJ Cost which is Strong importance compare to Cost of PEG=PPP.
- Select 3 = This mean that we evaluate RIC Cost which is Strong importance compare to Cost of PEG=PPP.

	Cost	Alternative Supplier	Most Important																	Most Important	Alternative Supplier
1	1.00	JPJ = JJJ	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9		RIC = RRR
	2.00	JPJ = JJJ	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9		PEG=PPP
	3.00	RIC = RRR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9		PEG=PPP

	Quality	Alternative Supplier	Most Important																	Most Important	Alternative Supplier
2	1.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9		RIC = RRR
	2.00	JPJ = JJJ	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9		PEG=PPP
	3.00	RIC = RRR	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9		PEG=PPP

	Delivery	Alternative Supplier	Most Important																	Most Important	Alternative Supplier
3	1.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9		RIC = RRR
	2.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9		PEG=PPP
	3.00	RIC = RRR	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9		PEG=PPP

	Financial Stability	Alternative Supplier	Most Important																	Most Important	Alternative Supplier
4	1.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9		RIC = RRR
	2.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9		PEG=PPP
	3.00	RIC = RRR	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9		PEG=PPP

	Technical Capability	Alternative Supplier	Most Important																	Most Important	Alternative Supplier
5	1.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9		RIC = RRR
	2.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9		PEG=PPP
	3.00	RIC = RRR	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9		PEG=PPP

Base on overall information Please mark or highlight in the box of the message that is true and important from your knowledge as much as possible for No. 6

	Overall	Alternative Supplier	Most Important																	Most Important	Alternative Supplier
6	1.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9		RIC = RRR
	2.00	JPJ = JJJ	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9		PEG=PPP
	3.00	RIC = RRR	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9		PEG=PPP

<u>Part 3</u> Recommendations

……

……

……

……

Appendix B

Response from Head of Procurement

Question Set 1

No.	Factor	Most Important																	Most Important	Alternative Supplier
1	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Quality
2	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Delivery
3	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Financial Stability
4	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Technical Capability
5	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Delivery
6	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Financial Stability
7	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Technical Capability
8	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Financial Stability
9	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Technical Capability
10	Financial Stability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Technical Capability

Response from Project Owner

Question Set 1

No.	Factor	Most Important								Most Important									Alternative Supplier
1	Cost	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	Quality
2	Cost	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	Delivery
3	Cost	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	Financial Stability
4	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	Technical Capability
5	Quality	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
6	Quality	9	**8**	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
7	Quality	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Technical Capability
8	Delivery	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	Financial Stability
9	Delivery	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	Technical Capability
10	Financial Stability	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	Technical Capability

Response from Procurement Engineer Specialist

Question Set 1

No.	Factor	Most Important								Most Important									Alternative Supplier
1	Cost	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	Quality
2	Cost	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	Delivery
3	Cost	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	Financial Stability
4	Cost	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	Technical Capability
5	Quality	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	Delivery
6	Quality	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
7	Quality	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Technical Capability
8	Delivery	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
9	Delivery	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	Technical Capability
10	Financial Stability	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	Technical Capability

Response from Project Manager

Question Set 1

No.	Factor	Most Important																	Most Important	Alternative Supplier
1	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Quality
2	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Delivery
3	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Financial Stability
4	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Technical Capability
5	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Delivery
6	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Financial Stability
7	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Technical Capability
8	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Financial Stability
9	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Technical Capability
10	Financial Stability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Technical Capability

Question Set 2 _ - Only Project Manager will evaluate this question

	Cost	Alternative Supplier	Most Important									Most Important									Alternative Supplier
1	1.00	JPJ	9	8	7	6	**5**	4	3	2		1	2	3	4	5	6	7	8	9	RIC
	2.00	JPJ	9	8	**7**	6	5	4	3	2		1	2	3	4	5	6	7	8	9	PEG
	3.00	RIC	9	8	7	6	5	4	**3**	2		1	2	3	4	5	6	7	8	9	PEG

	Quality	Alternative Supplier	Most Important									Most Important									Alternative Supplier
2	1.00	JPJ	9	8	7	6	5	4	3	2		1	**2**	3	4	5	6	7	8	9	RIC
	2.00	JPJ	9	8	7	6	5	4	**3**	2		1	2	3	4	5	6	7	8	9	PEG
	3.00	RIC	9	8	7	6	5	**4**	3	2		1	2	3	4	5	6	7	8	9	PEG

	Delivery	Alternative Supplier	Most Important									Most Important									Alternative Supplier
3	1.00	JPJ	9	8	7	6	5	4	3	**2**		1	2	3	4	5	6	7	8	9	RIC
	2.00	JPJ	9	8	7	6	5	4	**3**	2		1	2	3	4	5	6	7	8	9	PEG
	3.00	RIC	9	8	7	6	5	4	**3**	2		1	2	3	4	5	6	7	8	9	PEG

	Financial Stability	Alternative Supplier	Most Important									Most Important									Alternative Supplier
4	1.00	JPJ	9	8	7	6	5	4	3	2		1	2	**3**	4	5	6	7	8	9	RIC
	2.00	JPJ	9	8	7	6	5	4	3	**2**		1	2	3	4	5	6	7	8	9	PEG
	3.00	RIC	9	8	7	6	5	4	**3**	2		1	2	3	4	5	6	7	8	9	PEG

	Technical Capability	Alternative Supplier	Most Important									Most Important									Alternative Supplier
5	1.00	JPJ	9	8	7	6	5	4	3	2		1	**2**	3	4	5	6	7	8	9	RIC
	2.00	JPJ	9	8	7	6	5	4	3	**2**		1	2	3	4	5	6	7	8	9	PEG
	3.00	RIC	9	8	7	6	5	4	**3**	2		1	2	3	4	5	6	7	8	9	PEG

	Overall	Alternative Supplier	Most Important									Most Important									Alternative Supplier
6	1.00	JPJ	9	8	7	6	5	4	**3**	2		1	2	3	4	5	6	7	8	9	RIC
	2.00	JPJ	9	8	7	6	**5**	4	3	2		1	2	3	4	5	6	7	8	9	PEG
	3.00	RIC	9	8	7	6	5	**4**	3	2		1	2	3	4	5	6	7	8	9	PEG

Response from Plants and Operation Manager

Question Set 1

No.	Factor	Most Important								Most Important									Alternative Supplier
1	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
2	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
3	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
4	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
5	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
6	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
7	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
8	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
9	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
10	Financial Stability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability

Response from Procurement Manager

Question Set 1

No.	Factor	Most Important								Most Important									Alternative Supplier
1	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
2	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
3	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
4	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
5	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery
6	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
7	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
8	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial Stability
9	Delivery	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability
10	Financial Stability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Capability

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