



**VENDOR SELECTION PROCESS
FOR PIPE PRODUCTS USING
MULTI CRITERIA DECISION MAKING METHOD
IN PT. ABD**

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ABSTRACT

PT. ABD, a geothermal company, is located in Bandung. PT. ABD has to maintain the good performance of pipe products which used to drain the heat from geothermal resource to generator for generating the electricity. To purchase the pipe products, the company has Procurement division for conducting vendor selection. The current procurement system does not have a specific method, the company just conduct the vendor selection subjectively. The vendor selection needs to be objective to make the maintenance process can be done quickly and the possibility of accidents can be reduced. That's why a good vendor selection should consider about the quality, cost, and delivery of the pipe products that the vendor offer to the company. This research is conducted for selecting the vendor objectively by using Multi Criteria Decision Making method. Based on the calculation and analysis, PT. D is the selected vendor for pipe products with 8.20 of final score.

Keywords: Geothermal, Pipe Products, Procurement, Vendor Selection, Quality, Cost, Delivery, Analytic Hierarchy Process

CHAPTER I

INTRODUCTION

1.1. Problem Background

Indonesia is one of the largest volcanic regions in the world which has a very good geothermal prospects. In fact, Indonesia could be the best in the field of geothermal energy with the estimation in amount of 19,600 MW. This amount comes from the 217 prospects identified geothermal resources are widespread throughout the Indonesian archipelago.

With high energy resources, the demand for energy keep growing along with the population growth. The imbalance between supply of energy and demand of energy is still going on, while the commercial source of energy is used not for productive purposes. Therefore, now many companies engaged in the field of geothermal use the wealth of geothermal resources in Indonesia.

PT. ABD, an electricity generator company using geothermal, is located in Bandung, West Java that applied Integrated Control System in the operation of the steam and power plant. Integrated Control System is an integrated system setting for the operation which set the excess steam arising from fluctuation in wells or plant output through the system auto trimming valve, so that no steam venting of excess steam. To support the system, PT. ABD has to maintain the needs of the system. The maintenance is needed to keep the good performance of the system. One of the important things that should be well maintained is pipe products. The function of pipe products is to drain the heat from the resource to generator for producing electricity.

Supply Chain Management (SCM) is the one responsible to provide the pipe products. To purchase the pipe products, SCM has the procurement division that is in charge of the purchase of needed goods. The pipe products should be changed in

every 3 years to maintain the quality of the pipes and to avoid the accidents that may occur. Because of the pipes have certain specification that only several vendors can fulfill, it makes the pipes have expensive prices. The procurement division has to conduct vendor selection to choose the best vendor.

Currently, procurement process does not have a specific method which sometimes make the decision takes a long time and questionable. The current vendor selection system is done subjectively. It will be also unfair to the other vendors that are able to fulfill the needs of the company.

The procurement system, needs to be objective and efficient, so that the maintenance process can be done quickly and the possibility of accidents that could occur can be reduced. A good procurement system must have a certain method which consider about the quality, cost, and delivery as the criteria for the joining vendor to win the procurement.

1.2. Problem Statement

Based on the problem background above, these are the statements related to the problem:

1. How can the vendor selection process for pipe procurement in PT. ABD become more objective and faster?
2. How to apply the proper method using simple software?

1.3. Objectives

The main objectives of this research are as follow:

1. To identify proper vendor selection process in order to make the vendor selection process for pipe products become more objective and faster that focus on Quality, Cost, and Delivery (QCD)
2. To prepare the proper computerized calculation using spreadsheet software

1.4. Scopes

Due to the limited resource and time in finishing this research, there are some scopes in the observation:

1. This research was conducted from September until November 2015
2. The vendor alternatives are only five vendors
3. The type of procurement used is only direct selection procurement process
4. There is only one expert that will be source of this research

1.5. Assumptions

There is an assumption that later on must be applied in this research:

1. The maintenance for pipe products held in every three years

1.6. Research Outline

Chapter I

Introduction

This chapter explains about the background of problem occurred, problem statement, research objectives, scope, assumption and the description of research outline.

Chapter II

Literature Study

This chapter is consist of the literature study of the background.

Chapter III

Research Methodology

This chapter describes the flow of the whole process of the research. From initial observation, problem identification, literature study, data collection and analysis, until conclusion and recommendation of this research.

Chapter IV**Data Collection and Analysis**

This chapter delivers the explanation of the problem in the maintenance process, which is selecting the best vendor using AHP include with the result.

Chapter V**Conclusion and Recommendation**

This chapter gives the conclusion of the research along with the recommendation for the future research.

The study literature background of this research will be described in Chapter II.

CHAPTER II

LITERATURE STUDY

Procurement and Efficiency: A Literature Review

This literature review discusses achieving the standard of pipes according to procurement team in PT. ABD by having vendor selection use Analytic Hierarchy Process. The review specified on how to maximize the selection process in procurement with the Analytic Hierarchy Process. The review also will explain further about the geothermal energy in Indonesia as it one of the most influential nature resources to the life of Indonesian people and on the other side, this company one of the geothermal company in Indonesia. Criterias for standard of the pipes have been considered to reach the target of PT. ABD.

2.1. Geothermal Energy In Indonesia

Geothermal Energy defines as the core energy that comes from centre of the earth in a form of the super-heated water or steam aim to make the turbines run well in producing the electricity. The word “Geothermal” derives from *Geo* and *Therm* in Geek words, *Geo* has meaning as Earth while *Therm* means the heat. Thus, it well explained if the word Geothermal means heat from the earth. The heat of the earth itself approximately is around 5,000 degrees celcius. The process of formation geothermal energy comes from magma that stores energy in a point called *geothermal reservoir*. Of course, Indonesia becomes the country which has the largest geothermal energy, considering the position of islands in Indonesia surrounded by volcanoes. No wonder, if Indonesia got a nickname as *ring of fire*. Moreover, Darma, et al, (2010) stated that based on past experiences about black out occured alternately almost in every city in Indonesia caused by the economic crisis in 1997 that gave impact to the growth of power sector in Indonesia, the government then plan to maximizing the use of geothermal as alternative energy sources for fulfilling the needs of Indonesia’s electric power for possibility 20 years ahead. Indeed, the government’s plan has been discussed due to Indonesia has been

predicted by the National Geological Agency of Indonesia (NGAI) if the potential of geothermal energy itself is around 27,000 MegaWatt.

Dharma, et al, (2010) viewed if there are some aspects that may influence development of the geothermal industry in Indonesia such as: strong agreement from Indonesian government and/or alteration in regulation as this country tries to have recovery from crisis in 2003. Further, in this sector, the government offers some policies to the industry as to inviting them to take part in energy recovery by let the government reviewing the exploration activities as it is written in the Geothermal Regulation (PP) No. 27 Year 2003 to reduce the risk made by the industry also giving encouragement to the industry in order let them do the exploration activities. The Government of Indonesia (GOI) have some consideration during create the Law which as follows: (Saptadji, 2011)

- a. Geothermal as an alternative source of energy for Indonesia is believed able to increase the chances of people's welfare due to this huge energy potential are managed by the state and this energy are renewable.
- b. This renewable is fully supported since it is environmentally friendly and tend to not give negativ effects like the greenhouse effect.
- c. The use of geothermal energy as a primary energy will reduce the petroleum consumption, therefore it can store the petroleum for the next few years.
- d. The latest legislation (UU No.27/2003) is devoted to geothermal since the laws that have been existed before have not met the management of geothermal, surely it has hopes to continue to promote varied activities and business in the field of geothermal energy.
- e. As a legal basis to reorganize and improve administration, management and utilization of geothermal resources as well as comply with UU No. 33 paragraph 2 & 3 Year 1945 which the contents are:

“Cabang-cabang produksi yang penting bagi Negara dan yang menguasai hajat hidup orang banyak dikuasai oleh Negara” - UU No. 33 Ayat 2 Tahun 1945

Related to the UU No. 27/2003, the GOI then initiated to create regulation for geothermal business activities which written in Government Regulation No. 59/2007 and geothermal energy prices which explains about the primacy of geothermal energy as the major energy source rather than any other renewable energy. Besides that, the GOI are intensively inviting society to switch from the previous energy like petroleum, gas and fossil to this renewable energy due to the cost to produce this energy are lower than any other energies, thus it becomes a great chance for companies to expand this power plant in Indonesia (Darma, et al., 2010).

Meanwhile, the GOI has mission to maximizing the utilization 60% of the existing geothermal energy in Indonesia or generate about 10,000 MW power plant for Indonesia, and on the other side to fulfill the demand, then the companies both outside and within the country are currently make them competing to improve their own quality and even some of the companies already go one step ahead by directly explore the areas which previously untouched. According to by Dharma, et al (2010), “in regard to investment substance GOI also expected to be able to maintain Indonesian country risk, to set up competitive basic electricity price, to determine market-demand currency rate, to arrange clear fiscal regulations, and to implement contract sanctity.”

2.2. Procurement

Procurement, which is generally known as purchasing, is a department works its ways in order to procure goods needed by certain users for company matters. The department did what it takes in order to fulfill the request of the user on the field, which in this case is to procure the goods for a maintenance process, but still the budget that could be used is the budget from the Owner Expected budget. Then, the department decides which vendor could win the process according to the documents that are also requested by the user on the field. Then the procurement department make contract to the vendor as an invoice so that the buyer company has evidence that the goods has been bought by them (Trisakti, 2015).

Generally, the idea of procurement division is generally the same as purchasing division in other companies, but according to the meaning from the dictionaries, literally, purchase means to buy something and procure means to get or have something.

The Procurement flow can be described generally as below:

- a. Users on the fields decide whether the company need a material or service based on a specification the platform and ask procurement department to make the purchase order
- b. The purchase order is made by procurement department. Purchase order consist of material/service that is needed by the users. The purchase order is used to contact vendors using the methods used in the procurement such as Direct Appointment, Direct Selection, or Open Tender process.
- c. When it has been agreed, goods procured, and the contract has been made, the material will be sent to the warehouse which then will be used accordingly

The Methods in doing the procurement of the goods especially in geothermal companies, that are currently still under oil and gas companies, are divided into three, Open Tender, Direct Selection, and Direct Appointment. These method will described as follow:

1. Open Tender

It is a system for procurement of goods or service that is opened for all, which means all companies that feels that they are able to fulfill the needs can sign for the Tender process. However, the system still must refer to the supply chain management methods which declared on the official board of announcements of the needing oil and gas companies, newspaper, or electronic media. (Sunaryadi, 2015)

2. Direct Selection

Direct selection is for the tender written invitation at least to three Tender Participants. Any direct selection above the amount above should be with

the written jurisdiction from the officials for the goods/services that fulfill the conditions as follows: (Sunaryadi, 2015)

- a. The continued system from the failed closed Bidding process
- b. For the contract of house, building, warehouse, shore base, or dock leasing
- c. National furniture or portable camp fulfilling for housing or offices
- d. For replacement of materials with the same specification according to the proven evidence and only can be replaced by certain material only
- e. For obligated materials, at least engage two BUMN (State Owned Enterprises) or BUMD (Regional Owned Enterprises)

3. Direct Appointment

Direct appointment is a process in where the procurement of service or material by appointing directly to one chosen supplier. For the contract above the amount that already stated before there are several conditions to be fulfilled, such as: (Sunaryadi, 2015)

- a. It is an emergency situation and cannot tolerate further delay, but so must fulfill the situation as follows:
 - i. The highest authority of the KKKS (Oil and Gas company) must confirm the emergency situation to SKK MIGAS in 24 hours including the request to do direct appointment to fulfill the need
 - ii. The process does not need confirmation from SKK MIGAS at all if the situation cannot wait the confirmation
 - iii. When the emergency situation has been lifted, the contractor company must report and request for auditing to SKK MIGAS for all procurement process that has been done
- b. It is a continuity of the failed Open or Closed Tender process
- c. Procurement for the obligatory kinds of goods that is only manufactured by one company that has the status of BUMN (State Owned Enterprises) or BUMD (Region Owned Enterprises)

- d. Direct Appointment from the State Owned Enterprise KKKS to the supplier company of Oil and Gas BUMN that fulfill the requirement as follows:
 - i. Has or own the working facility where the ownership could be done through procurement or leasing mechanism
 - ii. Make written commitment to the highest authority of the State Owned Enterprise KKKS with the copy to SKK MIGAS, to increase the capabilities, including to increase the investment in the working facilities and mastering the higher technology in the maximum time of five years according to the agreement of the supplier company and the KKKS
 - iii. Fulfill the capability of treasury that is required from the State Owned Enterprise KKKS
 - iv. In order to have joint procurement, all KKKS that join, has to be a State Owned Enterprise KKKS

2.3. Suppliers Criteria

Giving the criterion for the suppliers that join the procurement are needed in order to make sure that the goods and/or services obtained from that certain supplier are credible and good used. With a qualified and credible company, comes qualified goods which, of course, will make the connection between companies strengthen and the goods procured is as good as it needs to be. The matters that should be considered to give criterion for the procurement process are:

- a. The credibility of the supplier

It is the ability of the certain supplier to always be able to keep the good reputation and its constituency in term of fulfilling the requests and procurement invoices from the other companies. This point, however, is a subjective matter, therefore, this matter can only be known based on the news that are flying around.

b. Distribution of the goods

This is about the flexibility of the procuring company to get the goods. This point can be described into two, the distance and the time of the distribution. The closer the from-and-to warehouse, the better, because this will make the distribution of the goods much faster and more likely in its best condition without any unwanted delays.

Then about the time point, the lesser the lead time, the better, because the faster the procuring company gets the material, a proper maintenance process cause a shorten shut down period for the plant.

c. Price Decision

The price is also one of the criterions that need to be considered. The price will be decided by the Owner Expected price on the first place, but the lesser the price given from the vendor, the better it is. However, the saying of “the quality of the product is directly proportional with its price” and goes with the lower the price, the lower the quality is not entirely true.

d. Quality of the product

The quality of the product can be seen from its documents. A credible company should have the needed documents that are supposedly needed in the procurement processes. The documents of the goods, in this case a geothermal pipe, should fulfill all the specification requested by the user. Sometimes, the suppliers don't have the needed documents with them. This makes the qualification for that certain suppliers worse than the others (Marlistya, 2011).

2.4. Criteria and Sub Criteria for Vendor Selection

There are 3 source of criteria and sub criteria for vendor selection that explain below as follow:

a. Company

The company decision is become source because all the criteria must meet the satisfaction of the company. It is because the company want to have a good product with the criteria that the company want

b. There are seven criteria that must be consideration in choosing supplier to meet various customer needs. The seven criteria is as follow: (Wu & Tsai, 2010)

Table 2.1 Criteria and Sub Criteria 1

Criteria	Sub Criteria
Price	Price differences
	Payment terms
	Quantity discount
	Product cost
	Total logistics management cost
Delivery	Lead time
	Delivery on time every time
	Distribution capacity
Production	Inventory management
	Transportation storage
	Production capacity
	New product development
Quality	Process capability
	Product reliability
	Quality assessment
	Percent of rejection
Service	Flexibility
	Communication ability
	Information sharing
Technology	Percent of research
	Up to date equipment
	Similar product
Organization	Organization structure
	Employee training system
	Number of employee
	Reputation

- c. In the Journal of Industrial Engineering and Management stated that there are six criteria that influence in vendor selection method which are: (Tahriri, Osman, Yusuff, & Esfandiary, 2008)

Table 2.2 Criteria and Sub Criteria 2

Criteria	Sub Criteria
Trust	Length of cooperation
	Re-win percentage
	Trust between key men
Quality	ISO 9001
	Package
	Warranty
	Customer focuses
Cost	Delivery cost
	Net price
	Ordering cost
Delivery	Capital investment
	Lead time
	Late delivery
	Location
Management	Quality problem
	Urgent delivery
	Honesty
	Procedural
	ISO 14001
	Machinery
	Infrastructure
	Layout
	Product line
Financial	Profit
	Finance stability
	Banking history
	Discount
	Turn over

2.5. Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a multi criteria decision analysis that assist the decision maker in terms of giving the right scores based on the questionnaires or other kinds of scientific research to decide based on it eigen-value that will be the final decision later.

It is a decision making method that will prioritize alternatives when multiple criteria and sub-criteria must be used. This method will allow the decision maker to structure a most complex problem in form of a hierarchy level. It is a method that simply rank the alternative courses of actions based on the decision's judgments concerning the importance of the criteria and the extent to which they are met (Benyoucef, 2006).

There are scales that could be used to quantify the managerial judgments, which can be seen in Table 2.3 below. This scale, however, are decided head on and already been agreed and used world widely along with AHP method.

Table 2.3 AHP Judgment Scale

Judgment	Numerical Rating
Extremely preferred	9
Very Strongly preferred	7
Strongly Preferred	5
Moderately Preferred	3
Equally Preferred	1
Intermediate Value between two adjacent judgments	2, 4, 6, and 8

The pairwise comparison information for each component of the problem is represented by a pairwise comparison matrix. The important advantage of AHP is that this method can measure the degree to which the decision maker's judgment is consistent because some inconsistencies are acceptable, and some are not in the real life. A slight inconsistency could ruin the whole decision making process. The point is that this AHP method could make sure that the inconsistency remains in a reasonable limit. (Benyoucef, 2006)

The steps to do AHP are as follows: (Haas, 2008)

1. State the objective, alternative, and criteria

First thing first as the multi criteria decision analysis, AHP needs to have criterions and alternatives and of course, it needs an objective. This matter, however, could be done personally or by the decision of the company or decision maker's upper level authority.

2. Perform Pairwise Comparison

By using a pairwise comparison, the relative importance of one criterion over another can be expressed. As been stated in Table 2.3 before, there are scales to decide the pairwise comparison. This scale will be calculated in shape of matrices.

3. Calculate Eigen vector

The eigenvector of the matrices will produce eigenvalue that will be the final score of the current criterion or alternative. The calculation will use a matrix algebra and iteration. Note, that iteration should be done more than once to make sure of its consistency. When the difference is not more than 0.01 of value, there will be no need of more iteration.

4. Compute Eigen value

After the calculation of eigenvector, the eigenvalue will be produced. Note that the calculation of the weight is not only for the criteria, it should be done either way for the alternatives. Then, the eigenvalue of each of the alternatives will be calculated based on the criteria. Then the final product is the decision maker will get the final score that will decide the score of each of the alternatives.

5. Compute Consistency Index

Consistency Index (CI) has to calculate to know the consistency level of respondent by subtracting the Eigen value with total criteria then divided it by total criteria minus 1.

6. Compute Consistency Ratio (CR)

Consistency Ratio (CR) is needed for checking the consistency of the data. CR is come from CI divided by Ratio Index (RI).

Table 2.4 Ratio Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The example of calculation in AHP is explained as follows: (Haas, 2008)

1. State the objective, criteria, and alternatives

- Objective: select a new car

- Criteria: Style, Reliability, Fuel Economy
 - Alternatives: A, B, C, D
2. Arrange the information in a hierarchical tree based on the data collected as can be seen in Figure 2.1 below

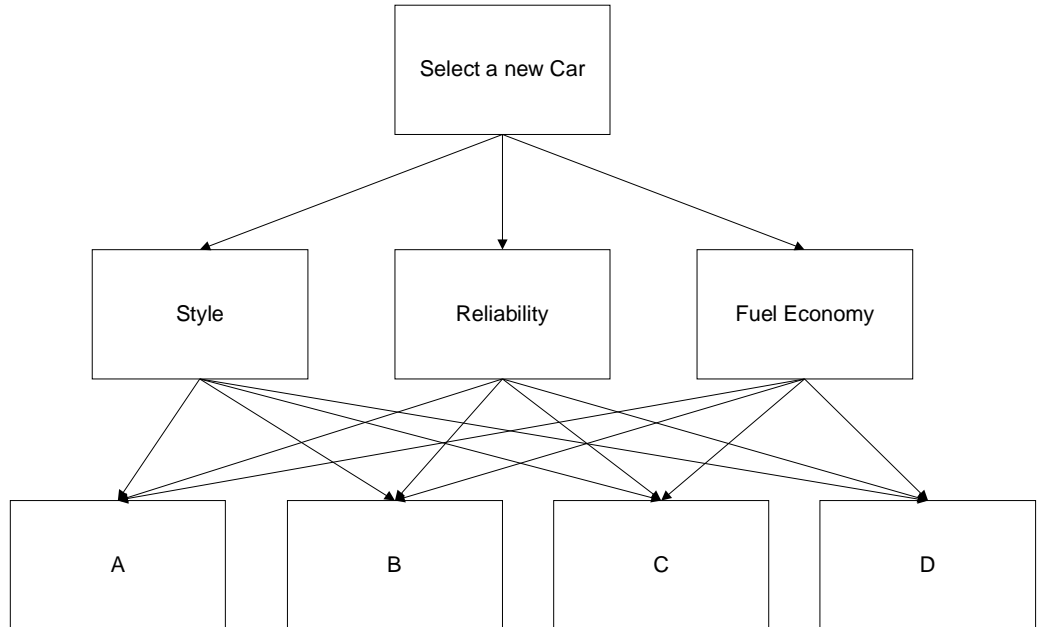


Figure 2.1 Car Selection Hierarchy Structure

3. Judge the scores for each criterion for each criterion, and later for alternatives, using AHP Judgment scale

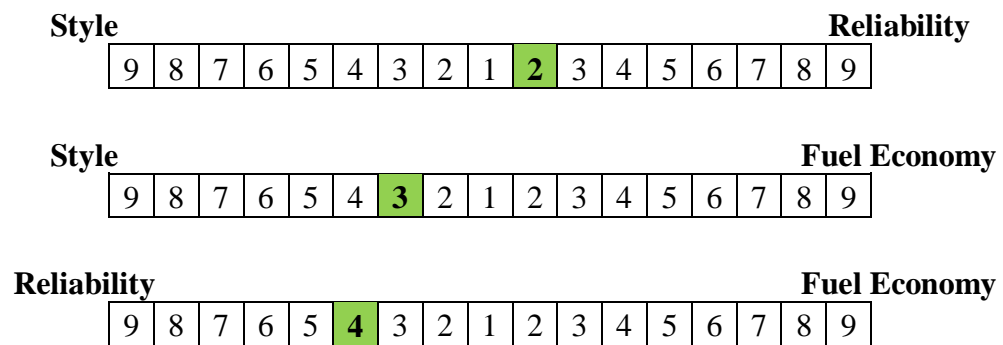


Figure 2.2 Pirwise Comparison Questionnaire

4. Make the matrix of pairwise comparison based on the judgment

$$\begin{array}{l} \text{Style} \\ \text{Reliability} \\ \text{Fuel Economy} \end{array} \begin{bmatrix} 1 & \frac{1}{2} & 3 \\ 2 & 1 & 4 \\ \frac{1}{3} & \frac{1}{4} & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0.5 & 3 \\ 2 & 1 & 4 \\ 0.33 & 0.25 & 1 \end{bmatrix}$$

5. Compute the eigenvector to get an eigenvalue. First, square the matrix.

$$\begin{array}{l} \text{Style} \\ \text{Reliability} \\ \text{Fuel Economy} \end{array} \begin{bmatrix} 1 & 0.5 & 3 \\ 2 & 1 & 4 \\ 0.33 & 0.25 & 1 \end{bmatrix}^2 = \begin{bmatrix} 3 & 1.75 & 8 \\ 5.3332 & 3 & 14 \\ 1.1667 & 0.6667 & 3 \end{bmatrix}$$

6. Compute the eigenvector by summing the rows horizontally, then sum the row totals. Then, normalize by dividing the horizontal row amount with the row total

$$\begin{bmatrix} 3 & 1.75 & 8 \\ 5.3332 & 3 & 14 \\ 1.1667 & 0.6667 & 3 \end{bmatrix} = \begin{array}{l} 12.75 \\ 22.3332 \\ 4.8333 \end{array} \sim 39.9165$$

$$\begin{array}{r} 12.75 \\ \hline 39.9165 \\ 22.3332 \\ \hline 39.9165 \\ 4.8333 \\ \hline 39.9165 \end{array} = \begin{array}{l} \mathbf{0.3194} \\ \mathbf{0.5595} \\ \mathbf{0.1211} \end{array}$$

7. Repeat from step 5 by using the new eigenvector matrix. Calculate the eigenvector one more time to make sure of its consistency. The iteration should be done if the difference of the eigenvector is too much (> 0.01)

$$\begin{bmatrix} \mathbf{0.3194} \\ \mathbf{0.5595} \\ \mathbf{0.1211} \end{bmatrix} - \begin{bmatrix} \mathbf{0.3196} \\ \mathbf{0.5584} \\ \mathbf{0.1220} \end{bmatrix} = \begin{bmatrix} \mathbf{0.0002} \\ \mathbf{0.0001} \\ \mathbf{0.0001} \end{bmatrix}$$

8. So, the last computed eigenvector gives the ranking of the criterion

$$\begin{array}{l} \text{Style} \\ \text{Reliability} \\ \text{Fuel Economy} \end{array} \begin{bmatrix} \mathbf{0.3196} \\ \mathbf{0.5584} \\ \mathbf{0.1220} \end{bmatrix} \sim \begin{array}{l} \text{Second most important} \\ \text{Most important criterion} \\ \text{Least important} \end{array}$$

9. Make the same matrix and calculation for pairwise comparison for the alternatives in terms of each of the criterion. For example in term of Style,

each alternative are given its own judgment scores. Then, it is calculated until each of the criterion gets its own eigenvalues for each alternatives

$$\begin{matrix} A \\ B \\ C \\ D \end{matrix} \begin{bmatrix} 1 & 1/4 & 4 & 1/6 \\ 4 & 1 & 4 & 1/4 \\ 1/4 & 1/4 & 1 & 1/5 \\ 6 & 4 & 5 & 1 \end{bmatrix}^2 \approx \begin{matrix} \mathbf{0.1160} \\ \mathbf{0.2470} \\ \mathbf{0.0600} \\ \mathbf{0.5770} \end{matrix}$$

10. Repeat this for all the alternatives on all criterion, then calculate the whole matrix to get the one that has the highest score

$$\begin{matrix} & \textit{Style} & \textit{Reliabilty} & \textit{Fuel} \\ A \\ B \\ C \\ D \end{matrix} \begin{bmatrix} 0.1160 & 0.3790 & 0.3010 \\ 0.2470 & 0.2900 & 0.2390 \\ 0.0600 & 0.0704 & 0.2120 \\ 0.5770 & 0.2570 & 0.2480 \end{bmatrix} \times \begin{bmatrix} 0.3196 \\ 0.5584 \\ 0.1220 \end{bmatrix}$$

Then, the decision maker will get the last value which is the weight of each criterion

$$\begin{matrix} A & 0.3060 \\ B & 0.2720 \\ C & 0.0940 \\ \mathbf{D} & \mathbf{0.3280} \end{matrix}$$

Alternative D has the highest value, which means the decision maker will most likely to choose alternative D among other alternatives.

The calculation that made in AHP are always guided by the expert's experience, and AHP can be considered as a tool to translate the evaluations of qualitative and quantitative made by the expert into multi criteria ranking. AHP is simple because it is no need to build a complex expert system with the expert's knowledge embedded in it. In additional, AHP is not require a large number of evaluations by the user, especially for problem that has less criteria and sub criteria. (Saaty, 1980)

After understanding the literature study of the background, the framework of this research will be explained in Chapter III.

CHAPTER III

RESEARCH METHODOLOGY

This chapter has explained the flow of whole processes of this research. The steps in this chapter will become a guide to do the research so the objectives of this research are reached.

3.1. Theoretical Framework

This research is conducting based on the procedure in Figure 3.1 below:

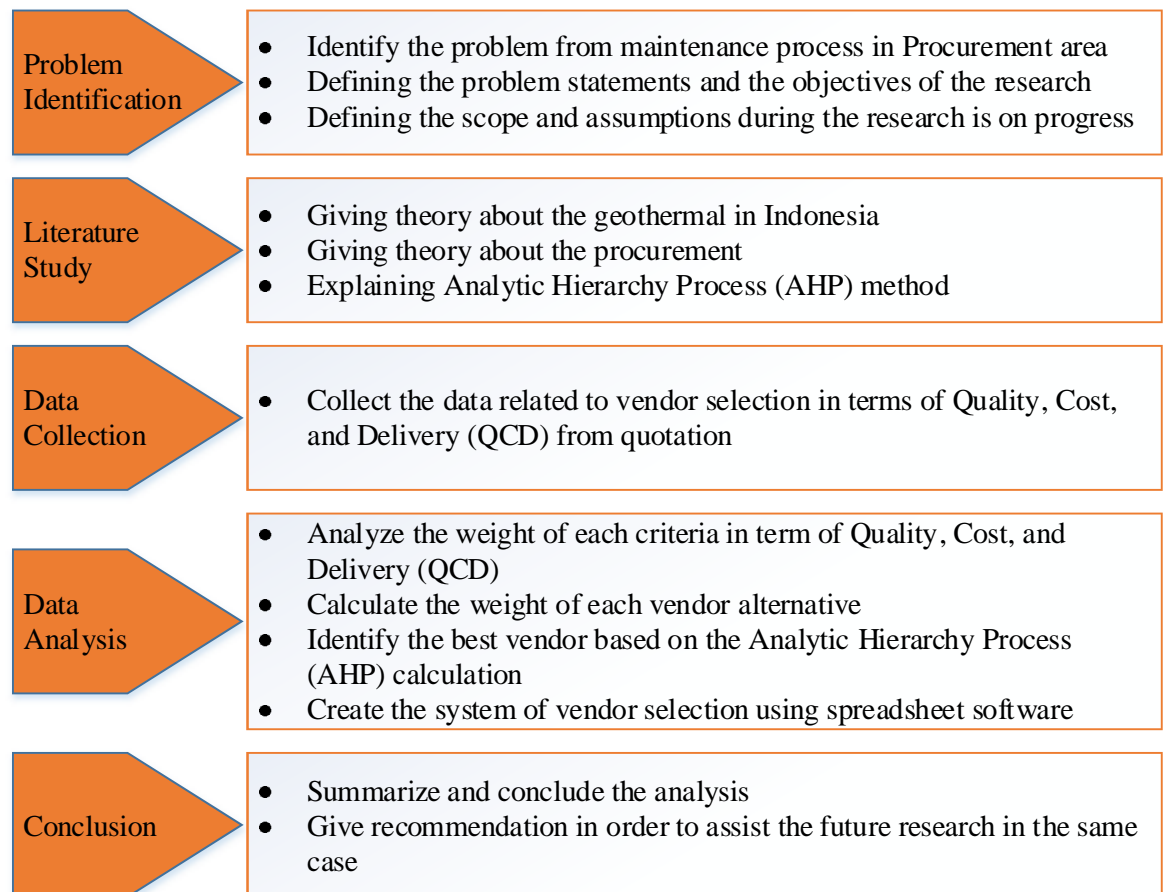


Figure 3.1 Theoretical Framework

3.1.1. Problem Identification

This step is conducted to identify the problem from maintenance activity at PT. ABD due to the selecting vendor for pipe products. By knowing the problem which

leads to the main purpose in conducting this research. The main objective of this research is to make the maintenance process become more efficient in terms of quality, cost and delivery (QCD) in order to make the procurement process for selecting the best vendor objectively.

After defining the objective, next step is defining the supporting aspects with purpose of help during this research conducted. The supporting aspects are the scope and the assumption. The scopes of this research are the research conducted in procurement area for maintenance, five vendors as the vendor alternatives with focus criteria on quality, cost, and delivery, and Analytic Hierarchy Process used as the method to selecting the vendors. The assumptions of this research are each vendor alternatives has the weight, so the analysis after calculation using Analytic Hierarchy Process (AHP) will be harder and only one criteria has extreme weight rather than other criteria. So the calculation Analytic Hierarchy Process (AHP) is not really needed.

3.1.2. Literature Study

In this step, the literature studies are used as the resource to review the materials relevant to the study. The theories are used as a guide to do the research. There are several points which are critical to this research. First is about geothermal. Second is about Supply Chain Management especially procurement process. The last is about Analytic Hierarchy Process (AHP) that used to selecting the best vendor.

3.1.3. Data Collection

During this step, all the data and information related to the five vendor alternatives and its quotation about the quality, cost, and delivery for the pipe products are gathered. The data are required to support the analysis.

3.1.4. Data Analysis

After collecting the quotations, the next step is calculating the data using Analytic Hierarchy Process (AHP) method. The score of each vendor alternative which the main point of this step is being analyzed to defining the best vendor.

3.1.5. Conclusion and Recommendation

The last step is to draw conclusion and give recommendations. The conclusion is the finding of research result and answering the research objectives. The recommendation is about the suggestion for those who would like to do some kind of research with a similar topic in purposed to the betterment of research in the future.

3.2. Research Framework

The research framework will describe the detail steps in this research. Figure 3.2 is all the steps to conducting this research.

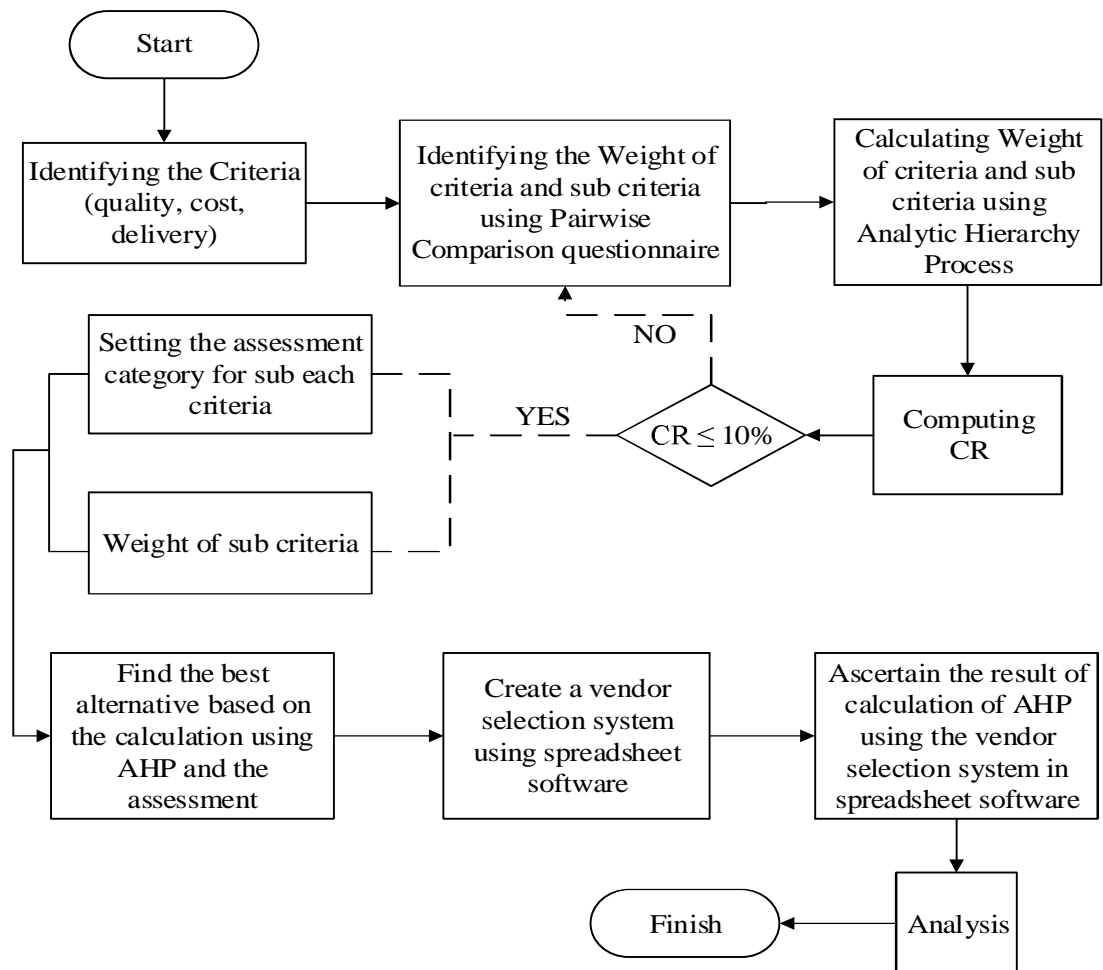


Figure 3.2 Research Framework

The description of the steps are:

1. Identifying the problem from the maintenance activity in procurement area due to vendor selection.
2. The data obtained from the vendor's quotation that focus on quality, cost, and delivery, and the questionnaire about the weight of each criteria.
3. Because the problem is about the vendor selection, Analytic Hierarchy Process (AHP) method is chosen to selecting the best vendor to purchase pipe products.
4. After collecting the data from quotation and questionnaire, the next step is calculating the data using AHP method.
5. The calculation using AHP is begin with calculating the weight of each criteria.
6. Compute the Consistency Ratio (CR) each criteria and sub criteria.
7. If CR is less than 10%, it means the data is consistent.
8. After knowing the data is consistent, then set the assessment category for each sub criteria.
9. To find the best vendor, the score from the assessment for each sub criteria is multiplying by the weight of sub criteria.
10. Create a vendor selection system using spreadsheet software to ascertaining the result of the calculation using AHP is right and helps the company to hold the vendor selection in next period.

After understanding the framework of this research, the data should be calculated and analyzed which can be seen in Chapter IV.

CHAPTER IV

DATA COLLECTION AND ANALYSIS

4.1. Vendor Performance Profile

There are five vendor alternatives that will be assessed to choose the best vendor for pipe products. The five vendor alternatives are PT. A, PT. B, PT. C, PT. D, and PT. E. Here are the vendor's quotations and the data obtain from the meeting with each vendor:

a. PT. A

The warehouse of PT. A located in Surabaya with the expectation time arrival (ETA) is 3 months and the cost of delivery is \$100 with 3 weeks installation time. The lifetime of the material is 3 years and given warranty for 6 months. PT. A stated that the maximum negotiation percentage is 8%.

Table 4.1 Vendor's Quotation PT. A

Description	Qty	UoM	Unit Price (USD)	Total Price (USD)
ASME B36.10M L 12M, ISO 9001 QM, OHSAS 18001, ISO 14001, API 5L & 6H, API Q1	80	Joint	\$ 890.00	\$ 71,200.00
Total Price				\$ 71,200.00

b. PT. B

The warehouse of PT. B located in Balikpapan with the expectation time arrival (ETA) is 3.5 months and the cost of delivery is \$170 with 1 week installation time. The lifetime of the material is 5 years and given no warranty. PT. B stated that the maximum negotiation percentage is 4%.

Table 4.2 Vendor's Quotation PT. B

Description	Qty	UoM	Unit Price (USD)	Total Price (USD)
ASME B36.10M Length of 12M, ISO 9001 QM, OHSAS 18001, API 5L & 6H, API Q1	80	Joint	\$ 770.00	\$ 61,600.00
Total Price				\$ 61,600.00

c. PT. C

The warehouse of PT. C located in Bandung with the expectation time arrival (ETA) is 2 months and the cost of delivery is \$55 with 15 days installation time. The lifetime of the material is 3 years and given warranty for 8 months. PT. C stated that the maximum negotiation percentage is 10%.

Table 4.3 Vendor's Quotation PT. C

Description	Qty	UoM	Unit Price (USD)	Total Price (USD)
ASME B36.10M, ISO 9001 QM, OHSAS 18001, ISO 14001, API 5L certificate	90	Joint	\$ 910.00	\$ 81,900.00
Total Price				\$ 81,900.00

d. PT. D

The warehouse of PT. D located in Jakarta with the expectation time arrival (ETA) is 2 months and free delivery service with 10 days installation time. The lifetime of the material is 3 years and given warranty for 6 months.

Table 4.4 Vendor's Quotation PT. D

Description	Qty	UoM	Unit Price (USD)	Total Price (USD)
ASME B36.10M L 12M, ISO 9001 QM, OHSAS 18001, ISO 14001, API 5L & 6H, API Q1	100	Joint	\$ 790.00	\$ 79,000.00
Total Price				\$ 79,000.00

e. PT. E

The warehouse of PT. E located in Batam with the expectation time arrival (ETA) is 3 months and free delivery service with 3 weeks installation time. The lifetime of the material is 4 years and given warranty for 1 year. PT. E stated that the maximum negotiation percentage is 2%.

Table 4.5 Vendor's Quotation PT. E

Description	Qty	UoM	Unit Price (USD)	Total Price (USD)
ASME B36.10M with Length 12M, ISO 9001 QM, OHSAS 18001, ISO 14001, API 5L & 6H, API Q1	90	Joint	\$ 880.00	\$ 79,200.00
Total Price				\$ 79,200.00

4.2. Criteria and Sub Criteria

The criteria and sub criteria will be foundation of vendor selection for pipe maintenance in PT. ABD. The sources of the criteria and sub criteria are from journal and company demand. The criteria and sub criteria describes in Table 4.6.

Table 4.6 Criteria and Sub Criteria choosen

No.	Criteria	Sub Criteria	Source
1	Quality	Product Specification	Wu (2010), Company
		Lifetime	Company
		Warranty	Tahriri (2008)
2	Cost	Cost of Material	Wu (2010)
		Maximum Negotiation	Wu (2010)
		Cost of Delivery	Tahriri (2008)
3	Delivery	Lead Time	Wu (2010)
		Installation Time	Company
		Location of Warehouse	Tahriri (2008)

Table 4.6 shows there are three criteria that will be the foundation of vendor selection for pipe maintenance; Quality, Cost, and Delivery. Quality and Cost has three sub criteria, and Delivery has two sub criteria.

Wu (2010) and Tahriri (2008) journal are being used as the reference for sub criteria of vendor selection. The expert of the company is the one who made the decision to choose the criteria and sub criteria needed.

Here are the brief explanation of each sub criterion:

a. Product Specification

The company requested the pipe products to have certain specification. Based on the request of the company, for the quality specification, the vendors shall have the following valid certificates such as:

1. ISO 9001 Quality Management System

ISO 9001 known as the standard of Quality Management System which intended to developing the management system in a company so that the company who already pass the standard can compete with other companies within local and international companies. Besides

that, by this standard, the owner can meet the official requirements with the basic that have been depicted and they also have big chance to emphasize their own values of business and establish the system with the intention of development progress. (Court, Avenue, & Keynes, 2013)

2. OHSAS 18001

OHSAS which stands for Occupational Health and Safety Management is a universal method used to test the quality of the management of health, safety and systems in a company with the aim to minimize the worst possible thing that can happen to workers or their external companies. Meanwhile, according to acsregistrars.com there will be some parts to be tested by OHSAS which following as: (a) the awareness of the staff and training program which given by the company, (b) response during an emergency situation, (c) the management system, (d) planning and risk assessment, (e) communication in safety management, and indeed (f) periodically checking and repairs.

Those tested parts based on NSAI are actually a tool used by the company to achieve OHSAS standards. This tool commonly referred as PDCA Cycle that allows the company to establish and keep maintaining health and safety rules regulations. PDCA itself is the abbreviation of **Plan – Do – Check – Act**.

In **Plan**, this is where the company start determining what the company wants to achieve and in what manner to be succeed. Next in **Do**, those plans that have been discussed during brainstorming, are being executed. When the execution begin, this the time where **Check** starts by the examination with the instructions of the standard OHSAS, other related terms, reports and the main goals whether it has been reached or not yet. The last step is **Act**, if the company

found something which is not appropriate with the standard then the company should decide the pace step to have some evaluation and improvement for those actions in order to conform with the OHSAS standards. (House, 2009)

3. ISO 14001

ISO 9001 focuses on giving great quality to meet the customer's satisfaction whereas this ISO14001 is Environmental Management System which specified in controlling the environmental impact caused by production process. This international standard point out several ways to improve the environmental aspects such as maximizing the use of existing resources, reduce the volume of waste generated during production proces, becoming superior in competing with other companies and of course earn trust from many people especially the important ones. This document, however, is really important because as a geothermal pipe it needs to have all the good environmental aspects. (Central, 2015)

4. API 5L and 6H Monogram certificate

This API certificate is not so different with the Q1 certificate. API 5L Specifications covers seamless and welded pipe suitable for use in conveying gas, water, oil, and other liquefied media. Specifications for API 5L adhere to the International Organization for Standardization ISO 3183, which standardizes pipeline transportation systems within the materials, equipment and offshore structures for petroleum, petrochemical, and natural gas industries. The technical committee authoring the standards recognized that there are two basic Product Specification Levels (PSL) of technical requirement and therefore developed PSL 1 and PSL 2. PSL 1 is a standard quality for line pipe where PSL 2 contains additional chemical, mechanical properties, and testing

requirements. While the 6H is to tell about the specification on its end closures, its type of connection, and swivels. (Federal, 2008)

5. API Q1 Certificate

In determining a vendor to decide ordering goods for company, procurement team should view in terms of quality possessed by those vendors. One of the ways that can be done is by looking at the company certification made by American Petroleum Institute (API). For this issue itself is by API Spec Q1 with its title "Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry".

Besides that to obtain official certification from API, quoted from thomasnet.com, the company then must fulfill some requirements requested such as:

- a. Four months before the submission of certification, the company already set up a quality system.
- b. Give quality manual as a sign of approval as well as host during the audit of the API in progress.
- c. Review which conducted must implement the quality manual.
- d. To assure all that still conducted are eligiblen, then the audit should be carried out once in a year.

Furthermore, based on the book Quality Manual of API 9th Edition (2014), the goal of creating such a standard certification is because the companies which focus in components' production oil and natural gas, need some sort of fundamental to keep quality flow of working in management, making the company well-prepared to meet the desires and needs of the client, and precisely understand the compatibility of the products. Hence, along with standardization, the company can evaluate the quality and improve it with intention to get huge customer's satisfaction with specific target like high-quality products and the process of production itself.

b. Lifetime

This sub criterion is the service duration of the pipe products. Because of the company held the maintenance in every three years, so the minimum lifetime should be 3 years.

c. Warranty

This sub criterion is the commitment of the vendor alternatives for changing the defect pipes on certain duration. After installing the pipes, the vendor should give warranty to the company. The period of warranty is based on the deal between the company and the vendor.

d. Cost of Material

For the cost of the product, the company requested that each joint's cost cannot exceed \$800. This cost request, however, does not include the cost of delivery.

e. Cost of Delivery

This criterion about the cost that the company should pay to the vendor for delivering the pipes. The cost is obtain from the meeting with each of the vendor.

f. Maximum Negotiation

This sub criterion consider about the discount that the vendor offer to the company. The discount can reduce the total cost that the company should pay to the vendor.

g. Lead Time

This sub criterion about the expectation time arrival that the vendor give to the company. The longer the lead time, the lesser the score of the vendor and it also reduce the possibility of the vendor to win the procurement process.

h. Installation Time

Beside lead time, installation time also a crucial sub criteria in deliverance. Installation time is calculated from the pipes come to the company's warehouse which located in Bandung until all the pipes have been installed. The longer the installation time also means the longer the time for the company to shut down the whole plant. Therefore, will reduce the profit of the company.

i. Location of Warehouse

This sub criterion is the distance from the company's warehouse where located in Bandung to the vendor's warehouse. The closer the distance can make the expert ease to control the order.

Figure 4.1 below shows the Hierarchy begin with the vendor selection for pipe maintenance as the objective of this research, continue with the criteria in the first level of Hierarchy structure, and the sub criteria in the second level. There are the vendor alternatives in the lowest level of the Hierarchy structure. To reach the objective of this research which is the top of the Hierarchy structure, those vendor alternatives will be evaluated with criteria and sub criteria, and ranked the vendor alternatives from the highest to the lowest rank.

There are five vendor alternatives that will be analyzed in Data Analysis. This five vendor alternatives are chosen by the company because the pipe products specification that they have can fulfill the requirement of the company's needs. So the direct selection method by the company is done in the beginning before it goes to Data Analysis.

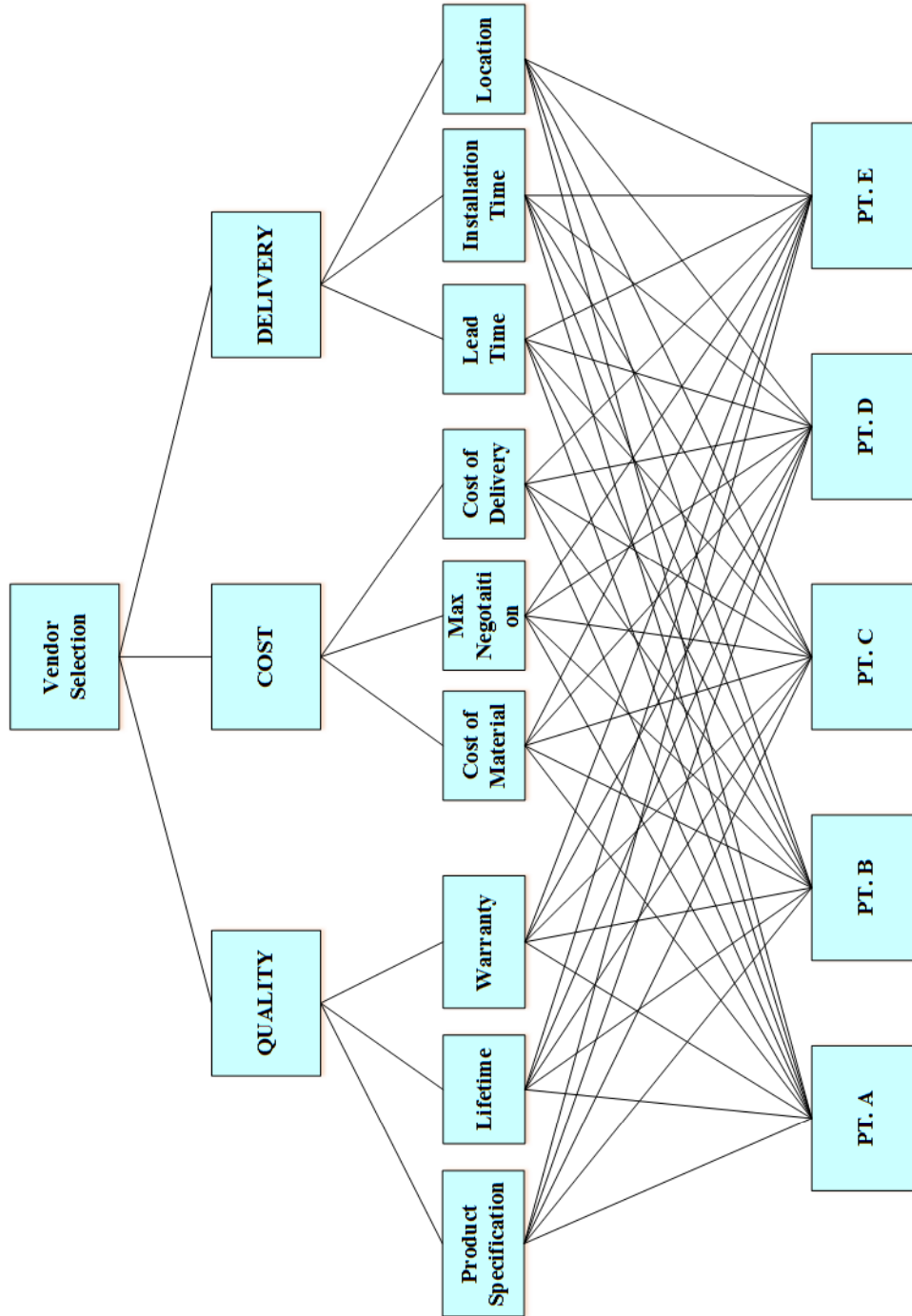


Figure 4.1 Hierarchy Structure

Table 4.7 shows the sub criteria that will be consider to selecting the best vendor for pipe maintenance.

Table 4.7 Summary of Criteria and Sub Criteria

Vendors	Specification	Lifetime (year)	Warranty (month)	Cost of Material	Max Negotiation	Cost of Delivery	Lead Time (month)	Install Time (day)	Location
PT. A	ISO 9001 QM, OHSAS 18001, ISO 14001, API 5L & 6H, API Q1	3	6	\$890	8%	\$100	3	21	Surabaya
PT. B	ISO 9001 QM, OHSAS 18001, API 5L & 6H, API Q1	5	no	\$770	4%	\$170	3.5	7	Balikpapan
PT. C	ISO 9001 QM, OHSAS 18001, ISO 14001, API 5L	3	8	\$910	10%	\$55	2	15	Bandung
PT. D	ISO 9001 QM, OHSAS 18001, ISO 14001, API 5L, API Q1	3	6	\$790	No	free	2	10	Jakarta
PT. E	ISO 9001 QM, OHSAS 18001, ISO 14001, API 5L & 6H, API Q1	4	12	\$880	2%	free	3	21	Batam

4.3. Expert Profile

There is only one expert who is the person in charge as the current procurement supervisor. It is because in one day, there are so many procurement process happened. So, the processes should be distributed evenly to the PICs, or in this case called the experts.

The current expert is chosen mainly because he already experienced and been in oil and gas procurement process for 7 years now and mostly, he procured the goods for the geothermal plant needs, including this pipe for maintenance.

4.4. Data Analysis

The weight of each sub criterion will be calculated using the Analytic Hierarchy Process (AHP) method. Then, based on the calculation the result will be ascertained with the result from the vendor selection system using spreadsheet software.

4.4.1. Analytic Hierarchy Process (AHP) Calculation

The calculation using Analytic Hierarchy Process (AHP) method begin with calculating the weight of the criteria using pairwise comparison method. Pairwise comparison method is using questionnaire that fulfill by the expert. The expert gave the score for each criteria and sub criteria.

The rating score for pairwise comparison is from 1 until 9. If one criteria has the important value than the comparison, so it has score greater than the comparison. The score of the one that has lesser value than the comparison is 1 divided by the score of the greater one.

Table 4.8 is the pairwise comparison questionnaire for the criteria. Quality is five times more important than Cost, Quality is three times more important than Delivery, and Delivery is five times more important than Cost.

Table 4.8 Pairwise Comparison Questionnaire for Criteria

Quality									Cost								
9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
Quality									Delivery								
9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
Cost									Delivery								
9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9

Table 4.9 is the input from the questionnaire. Because Quality score is five times cost, so the score of Cost is the reciprocal of it or equal to 1/5. The score of Delivery compare with Quality is the reciprocal from the score of Quality, 1/2. The score of Cost compare with Delivery is 1/5, it comes from the reciprocal of

Table 4.9 Pairwise Comparison between Criteria

	Quality	Cost	Delivery
Quality	1.00	5.00	2.00
Cost	0.20	1.00	0.20
Delivery	0.50	5.00	1.00
Total	1.70	11.00	3.20

Next step is calculating the normalization of the criteria weight. The calculation of geometric mean is skipped because only one respondent. The normalization value is come from the score of comparison between criteria divided by its value of total in each column. The result of normalization calculation shows in Table 4.10.

$$Normalization\ value = \frac{0.2}{1.70} = 0.12$$

Table 4.10 Normalization of Criteria

	Quality	Cost	Delivery
Quality	0.59	0.45	0.63
Cost	0.12	0.09	0.06
Delivery	0.29	0.45	0.31
Total	1.00	1.00	1.00

After calculating the normalization value of each comparison criteria, then continue to calculate the weight of pairwise comparison between criteria. The weight of pairwise comparison is come from the average of each row. The weight of comparison is the quota of each criteria in vendor selection process.

$$Weight = \frac{0.59 + 0.45 + 0.63}{3} = 0.56$$

Table 4.11 Weight of Pairwise Comparison between Criteria

	Quality	Cost	Delivery	Weight
Quality	0.59	0.45	0.63	0.56
Cost	0.12	0.09	0.06	0.09
Delivery	0.29	0.45	0.31	0.35
Total	1.00	1.00	1.00	1.00

Table 4.11 shows the weight of pairwise comparison between criteria. Quality is the greatest weight of pairwise comparison between criteria with value 0.56, continue with Delivery that has value 0.35, and the last is Cost with value 0.09.

Next is calculating the Eigen value of this matrix. But before calculating Eigen value, the score of pairwise comparison between criteria has to multiply by the weight of pairwise comparison between criteria.

Quality	1.00	5.00	2.00	<i>x</i>	0.56	=	1.72
Cost	0.20	1.00	0.20		0.09		0.27
Delivery	0.50	5.00	1.00		0.35		1.08

Figure 4.2 Calculation of eigen Vector

After multiplied the score of pairwise comparison between criteria has by the weight of pairwise comparison between criteria, then calculate the Eigen value. The Eigen value is come from the average of output pairwise comparison multiplied divided by the weight of pairwise comparison each criteria.

$$Eigen\ value = \frac{(\frac{1.72}{0.56} + \frac{0.27}{0.09} + \frac{1.08}{0.35})}{3} = 3.05$$

Consistency Index (CI) has to calculate to know the consistency level of respondent by subtracting the Eigen value with total criteria then divided it by total criteria minus 1.

$$CI = \frac{3.05 - 3}{3 - 1} = 0.027$$

After calculating CI, Consistency Ratio (CR) is computed for checking the consistency of the data. The data is consistent when CR is less than 10%. CR come from CI divided by Ratio Index (RI). The value of RI is based on Table 2.4, the value of RI with three criteria is 0.58.

$$CR = \frac{0.027}{0.58} = 0.0465$$

For the weight of each sub criterion can be calculated with the same step of Analytic Hierarchy Process method. The process of calculation using AHP for all sub criteria will be shown in Appendix 2. Table 4.12 shows the summary of the weight each criterion and its quota in the vendor selection process. The contain of Table 4.11 are Weight for each criteria and its sub criteria, and Eigen value, Consistency Index, and Consistency Ratio for each criteria.

Table 4.12 Summary of Weight of Each Criteria and Sub Criteria

Criteria and Sub Criteria	Weight	Eigen value	CI	CR
Quality	0.56	3.074	0.037	0.064
Product Specifications	0.34			
Lifetime	0.15			
Warranty	0.07			
Cost	0.09	3.018	0.009	0.016
Product cost	0.06			
Max negotiation	0.02			
Delivery time	0.01			
Delivery	0.35	3.066	0.033	0.056
Lead time	0.23			
Installation time	0.10			
Location	0.03			
Quality, Cost, Delivery		3.054	0.027	0.046

As it is states that the objective is for selecting the best vendor objectively not subjectively, so there will be no comparison between the vendor alternatives. The assessment of the best vendor should come from the weight of sub criteria each the vendor alternatives.

4.4.2. Assessment for Vendor Alternatives per Each Sub Criterion

Every sub criteria in each vendor alternatives has the score. The score come from the questionnaire that fulfill by the expert. The expert fulfill the questionnaire based on the quotation each vendor alternatives. The score is from 1 to 10. Here are the scale of the judgment for sub criteria.

a. Quality

Table 4.13 shows the scale for product specifications. The company prefers to the vendor alternatives complete all the quality documents requirements. It is given a score of 10 for the vendor who can submit all the documents completely. The rest of scaling are decided by the description that are stated before.

Table 4.13 Scale for Product Specification

Scale	Description
10	Has all of the specification
9	Has no OHSAS 18001
8	Has no ISO 9001
7	Has no ISO 14001
6	Has no API Q1
5	Has no API 5L & 6H
4	Has no OHSAS 18001, ISO 9001, and ISO 14001
3	Has no ISO 14001, and API Q1
2	Has no OHSAS 18001, ISO 14001, and API Q1
1	Has no API Q1, and API 5L & 6H

Table 4.14 shows the scale for lifetime of the product. The company prefers to the vendor alternatives with minimum 3 years product lifetime. It is given a score of 7 for the vendor who can give the standard pipes lifetime. If the vendor alternatives can give longer lifetime it gets more scores.

Table 4.14 Scale of Lifetime

Scale	Description
10	More than 5 years of lifetime
9	Has 4 - 5 years of lifetime
8	Has 3 - 4 years of lifetime
7	Has 2 - 3 years of lifetime
6	Has 2 - 2.5 years of lifetime
5	Has 1 - 2 years of lifetime
4	Has 1 - 1.5 years of lifetime
3	Has 0.5 - 1 years of lifetime
2	Has 0 - 0.5 years of lifetime
1	Has 0 years of lifetime

Table 4.15 shows the scale for warranty of the product. The company prefers to the vendor alternatives with minimum 8 months warranty. It is given a score of 7 for the vendor who can give the standard of warranty. If the vendor alternatives can give longer warranty it gets more scores.

Table 4.15 Scale of Warranty

Scale	Description
10	More than 2 years of warranty
9	Has 1 - 1.5 years of warranty
8	Has 8 month - 1 years of warranty
7	Has 7 - 8 months of warranty
6	Has 6 - 7 months of warranty
5	Has 5 - 6 months of warranty
4	Has 4 - 5 months of warranty
3	Has 3 - 4 months of warranty
2	Has 1 - 3 months of warranty
1	Has less than 1 months of warranty

b. Cost

Table 4.16 shows the scale for cost of the product. The company prefers to the vendor alternatives with minimum price \$800 per unit. It is given a score of 7 for the vendor who can give the standard of price. If the vendor alternatives can give cheaper price it gets more scores.

Table 4.16 Scale of Cost of Material

Scale	Description
10	The product cost is less than \$ 500
9	The product cost is \$ 500 - \$ 600
8	The product cost is \$ 600 - \$ 700
7	The product cost is \$ 700 - \$ 800
6	The product cost is \$ 800 - \$ 900
5	The product cost is \$ 900 - \$ 1000
4	The product cost is \$ 1000 - \$ 1100
3	The product cost is \$ 1100 - \$ 1200
2	The product cost is \$ 1200 - \$ 1300
1	The product cost is more than \$ 1300

Table 4.17 shows the scale for maximum negotiation. The company prefers to the vendor alternatives with minimum 10% discount. It is given a score of 7 for the vendor who can give the standard of discount. If the vendor alternatives can give greater discount it gets more scores.

Table 4.17 Scale of Maximum Negotiation

Scale	Description
10	Has more than 20% of product discount
9	Has 16 - 20% of product discount
8	Has 11 - 15% of product discount
7	Has 9 - 10% of product discount
6	Has 7 - 8% of product discount
5	Has 5 - 6% of product discount
4	Has 3 - 4% of product discount
3	Has 2% of product discount
2	Has 1% of product discount
1	Has 0% of product discount

Table 4.18 shows the scale for delivery cost. The company prefers to the vendor alternatives with minimum \$100 delivery cost. It is given a score of 7 for the vendor who can give the standard of delivery cost. If the vendor alternatives can give cheaper delivery cost it gets more scores.

Table 4.18 Scale of Delivery Cost

Scale	Description
10	The delivery cost is free
9	The delivery cost is around 0 - \$ 50
8	The delivery cost is around \$ 50 - \$ 70
7	The delivery cost is around \$ 70 - \$ 100
6	The delivery cost is around \$ 100 - \$ 120
5	The delivery cost is around \$ 120 - \$ 150
4	The delivery cost is around \$ 150 - \$ 170
3	The delivery cost is around \$170 - \$ 200
2	The delivery cost is around \$ 200 - \$ 220
1	The delivery cost is more than \$ 220

c. Delivery

Table 4.19 shows the scale for lead time. The company prefers to the vendor alternatives with minimum 3 months expected time arrival. It is given a score of 7 for the vendor who can give the standard of delivery time. If the vendor alternatives can give shorter delivery time it gets more scores.

Table 4.19 Scale of Lead Time

Scale	Description
10	The estimated time arrival is less than 1 month
9	The estimated time arrival is 1 - 1.5 months
8	The estimated time arrival is 1.5 - 2 months
7	The estimated time arrival is 2 - 2.5 months
6	The estimated time arrival is 2.5 - 3 months
5	The estimated time arrival is 3 - 3.5 months
4	The estimated time arrival is 3.5 - 4 months
3	The estimated time arrival is 4 - 4.5 months
2	The estimated time arrival is 4.5 - 5 months
1	The estimated time arrival is more than 5 months

Table 4.20 shows the scale for installation time. The company prefers to the vendor alternatives with minimum 15 days installation time. It is given a score of 7 for the vendor who can give the standard of installation time. If the vendor alternatives can give shorter installation time it gets more scores.

Table 4.20 Scale of Installation Time

Scale	Description
10	The installation time is less than 5 days
9	The installation time is 5 - 9 days
8	The installation time is 10 - 14 days
7	The installation time is 15 - 19 days
6	The installation time is 20 - 24 days
5	The installation time is 25 - 29 days
4	The installation time is 30 - 34 days
3	The installation time is 35 - 39 days
2	The installation time is 40 - 44 days
1	The installation time is more than 45days

Table 4.21 shows the scale for location warehouse. The company prefers to the distance of vendor alternatives' warehouse to company's warehouse is minimum 900 km. It is given a score of 7 for the vendor who has distance warehouse around that standard. If the vendor alternatives has shorter distance of warehouse it gets more scores.

Table 4.21 Scale of Location

Scale	Description
10	The location from warehouse is less than 300 km
9	The location from warehouse is around 300-500 km
8	The location from warehouse is around 500-700 km
7	The location from warehouse is around 700-1000 km
6	The location from warehouse is around 1000-1300 km
5	The location from warehouse is around 1300-1600 km
4	The location from warehouse is around 1600-2000 km
3	The location from warehouse is around 2000-2300 km
2	The location from warehouse is around 2300-2500 km
1	The location from warehouse is more than 2500 km

Those scale was made after consulting with the expert. Those scale will be the references for the expert in fulfilling the questionnaire.

After the judgment scale for sub criteria was made and the questionnaire was filled by the expert, next step is calculating the final score of each vendor alternatives. Here are the final weight calculation for each vendor alternatives. The final result for this calculation will give the decision maker the most possible answer.

a. PT. A

The final score of PT. A is come from multiplying the score of sub criteria of PT. A by the standard weight of sub criteria that calculated before.

Table 4.22 Final Score Calculation of PT. A

	Sp	Lt	Wr	Cm	Mn	Dc	Ld	In	Lo	\times	Weight	$=$	7.43
	10	7	5	6	6	7	6	6	5		0.34		
											0.15		
											0.07		
											0.06		
											0.02		
											0.01		
											0.23		
											0.10		
											0.03		

The final score of PT. A is **7.43**

b. PT. B

The final score of PT. B is come from multiplying the score of sub criteria of PT. B by the standard weight of sub criteria that calculated before.

Table 4.23 Final Score Calculation of PT. B

	Sp	Lt	Wr	Cm	Mn	Dc	Ld	In	Lo		Weight		
	7	9	1	7	4	4	5	9	3	x	0.34	$=$	6.44
PT. B	7	9	1	7	4	4	5	9	3		0.06		
											0.02		
											0.01		
											0.23		
											0.10		
											0.03		

The final score of PT. B is **6.44**

c. PT. C

The final score of PT. C is come from multiplying the score of sub criteria of PT. C by the standard weight of sub criteria that calculated before.

Table 4.24 Final Score Calculation of PT. C

	Sp	Lt	Wr	Cm	Mn	Dc	Ld	In	Lo		Weight		
	6	7	7	6	7	9	8	7	10	x	0.34	$=$	6.93
PT. C	6	7	7	6	7	9	8	7	10		0.06		
											0.02		
											0.01		
											0.23		
											0.10		
											0.03		

The final score of PT. C is **6.93**

d. PT. D

The final score of PT. D is come from multiplying the score of sub criteria of PT. D by the standard weight of sub criteria that calculated before.

Table 4.25 Final Score Calculation of PT. D

	Sp	Lt	Wr	Cm	Mn	Dc	Ld	In	Lo	x	Weight	$=$	8.20
											0.34		
											0.15		
											0.07		
											0.06		
PT. D	10	7	5	7	1	10	8	8	10		0.02		
											0.01		
											0.23		
											0.10		
											0.03		

The final score of PT. D is **8.20**

e. PT. E

The final score of PT. E is come from multiplying the score of sub criteria of PT. E by the standard weight of sub criteria that calculated before.

Table 4.26 Final Score Calculation of PT. E

	Sp	Lt	Wr	Cm	Mn	Dc	Ld	In	Lo	x	Weight	$=$	7.79
											0.34		
											0.15		
											0.07		
											0.06		
PT. E	10	8	8	6	3	10	6	6	6		0.02		
											0.01		
											0.23		
											0.10		
											0.03		

The final score of PT. E is **7.79**

From the calculation about final score of each vendor alternatives above shows that PT. D is the best vendor with value 8.20. However, to ease the calculation for this current process the company can use the formula system provided by Ms. Excel about the vendor selection for pipes maintenance. This system can be used for every three years when the maintenance pipe is needed.

4.4.3. Sensitivity Analysis

The vendor selection is held in every three years because the last vendor selected does not mean the best vendor for this procurement period. To gain more optimal result in vendor selection for next three years, Analytic Hierarchy Process method is chosen to be the method of analysis with the criteria of Quality, Cost, and Delivery. To prove the effectiveness of the propose method is better than the last method which is subjective analysis, sensitivity analysis is done.

Sensitivity analysis is method used to aware the effects of changing decision. The process is analyze the last decision taken and its effects compare with the propose decision taken and its effects. Below is the analysis of the last vendor selected, which is PT. C.



Figure 4.3 The Score of PT. C as the Last Vendor Selected

Previously, PT. C was chosen as the vendor selected subjectively by the company. According to the company, to reduce capital cost is the effective way in vendor selection. However, because of low price of the pipe products, the quality of the product is also poor. This caused the company to expense for maintenance cost more often in the whole three years.

Therefore, in this research, AHP method is proposed in order to build some considerations and each importance that the company did not notice and predict before.

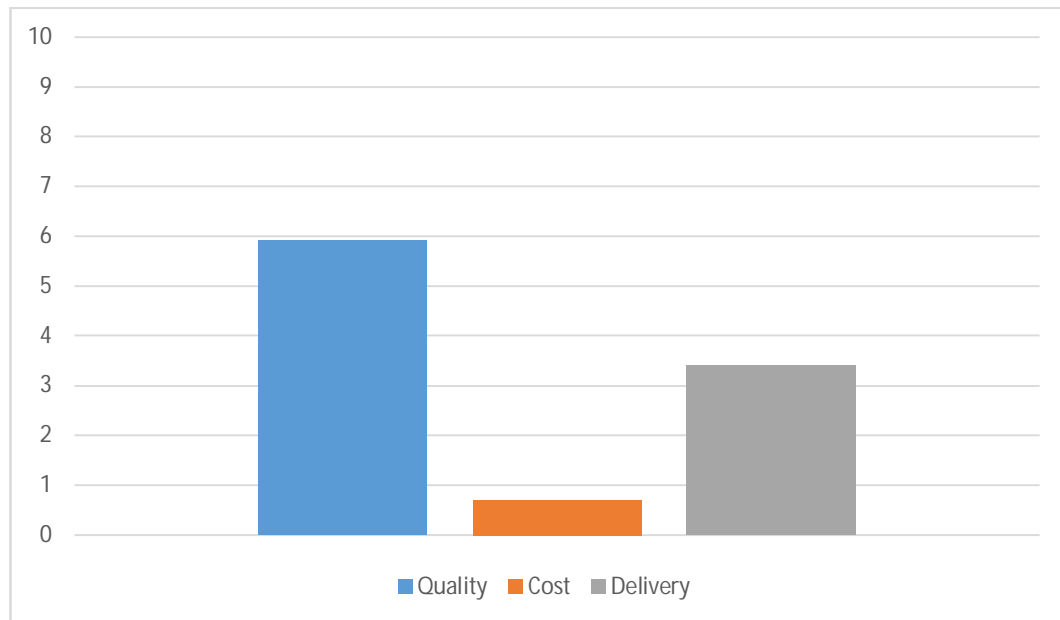


Figure 4.4 The Score of PT. D as the Vendor Propose

From the analysis using AHP, the vendor selected is PT. D. Even though there is significant change in cost that makes the company to expense more in capital, but the other considerations ensure the decision is right because the company does not have to expense on maintenance cost anymore. Besides, in selecting vendor using AHP, the things considered are product specification, lifetime, warranty, product cost, maximum negotiation, delivery cost, lead time, installation time, and warehouse location.

4.4.4. The Vendor Selection System using Spreadsheet Software

Knowing that the Analytic Hierarchy Process method is effective for vendor selection, hopefully this method will be used for the next vendor selection. Because of the criteria in selecting vendor are always the same, the spreadsheet can be made in order to make it easier for the company to define the best vendor in the future. The spreadsheet is in the form of tables, which are explain as below.

Table 4.27 Blank Sheet of Assessment Form

PT. A	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
PT. B	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
PT. C	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
PT. D	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
PT. E	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location

Table 4.27 is the form of assessment for each vendor alternatives that will assessed on the system. The score from each vendor alternatives are based on the quotation of each vendor alternatives in Table 4.1, Table 4.2, Table 4.3, Table 4.4, Table 4.5 and the assessment scale in Table 4.13, Table 4.14, Table 4.15, Table 4.16, Table 4.17, Table 4.18, Table 4.19, Table 4.20, and Table 4.21.

Table 4.28 below shows the filled assessment form that filled by the expert according to the quotation and the assessment scale. After all the vendor alternatives already assessed and filled by the score on the assessment form, then it continue to the next step which is final calculation for vendor selection.

Table 4.28 Filled Sheet of Assessment Form

PT. A	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
	10	7	5	6	6	7	6	6	5
PT. B	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
	7	9	1	7	4	4	5	9	3
PT. C	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
	6	7	7	6	7	9	8	7	10
PT. D	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
	10	7	5	7	1	10	8	8	10
PT. E	Quality			Cost			Delivery		
	Specs	Lifetime	Waranty	Product Cost	Max Nego	Deliv Cost	Lead time	Install time	Location
	10	8	8	6	3	10	6	6	6

Table 4.29 below is the form in spreadsheet software of final calculation for each vendor alternatives to choose the best vendors for pipe products. The score from each vendor alternatives are based on Table 4.28. The score of weight is come from AHP calculation based on Table 4.12.

Table 4.30 below shows the filled final calculation. The score of 8.20 is come from every sub criteria multiplied by weight of each sub criteria, $(10 \times 0.34 + 7 \times 0.15 + 5 \times 0.07 + 7 \times 0.06 + 1 \times 0.02 + 10 \times 0.01 + 8 \times 0.23 + 8 \times 0.1 + 10 \times 0.03)$. So, after all the vendor alternatives being calculated, the best vendor is PT. D with the score of 8.20.

Table 4.29 Blank Sheet of Final Calculation

	Specs	Lifetime	Warranty	Product cost	Max nego	Deliv cost	Lead time	Install time	Location
PT. A									
PT. B									
PT. C									
PT. D									
PT. E									

x

Weight
0.34
0.15
0.07
0.06
0.02
0.01
0.23
0.10
0.03

Table 4.30 Filled Sheet of Final Calculation

	Specs	Lifetime	Warranty	Product cost	Max nego	Deliv cost	Lead time	Install time	Location
PT. A	10	7	5	6	6	7	6	6	5
PT. B	7	9	1	7	4	4	5	9	3
PT. C	5	7	3	9	8	9	5	3	6
PT. D	10	7	5	7	1	10	8	8	10
PT. E	10	8	8	6	3	10	6	6	6

x

Weight
0.34
0.15
0.07
0.06
0.02
0.01
0.23
0.10
0.03

=

7.43
6.44
5.34
8.20
7.79

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Based on the analysis that has been done, there are 2 points that can be concluded, which are:

- a. The vendor selection process of the procurement for pipe products become more objective and faster. It is because the propose method used in vendor selection is Analytic Hierarchy Process that focus on three criteria which are Quality, Cost, and Delivery select the best vendor objectively with Quality as the most important criteria. The result shows that PT. D is the best vendor with 8.20 of final score.

- b. Knowing that the Analytic Hierarchy Process method is effective for vendor selection, hopefully this method will be used for the next vendor selection. Because of the criteria in selecting vendor are always the same, the spreadsheet can be made in order to make it easier for the company to define the best vendor in the future.

5.2. Recommendation

After this research is done, there are several points that can be focusing on future research:

- a. For further research on the similar topic needs to add or using another method such as Analytic Network Process and Promethee to make the result more trusted.

- b. Added more criteria and sub criteria for the Analytic Hierarchy Process, so the assessment is not only focused on 3 criteria and 9 sub criteria.

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