SUPPLY CHAIN DECISION MAKING USING ANALYTICAL HIERARCHY PROCESS (AHP): A PHARMACEUTICAL INDUSTRY CASE STUDY

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ABSTRACT

Decision making have been widely used in our life especially in industrial problems. Correct decision making in solving supply chain problem is not straight forward. Many criteria have to be considered in order to solve the problem and therefore it difficult to solve. In order to help supply chain department in industries, this thesis work introduce a decision making process called Analytical Hierrchy Process (AHP) to solve the decision making problem in supply chain. These methods are not widely use in Malaysia even though this method has been around for almost 40 years. This thesis also will take one industrial company as a case study to help them solving the problem in their supply chain by using Analytical Hierarchy Process (AHP). The result from case study shows that the approach is able to evaluate a justified decision and could be used to solve other problem. This case study will become an example for other industries to practice Analytical Hierarchy Process (AHP).

ABSTRAK

Proses membuat keputusan telah digunakan secara meluas dalam kehidupan kita terutamanya di dalam masalah industri. Membuat keputusan yang betul dalam menyelesaikan masalah rantaian pengagihan adalah sangat sukar. Banyak kriteria perlu di ambil kira dalam usaha menyelesaikan masalah dan kriteria yang berbeza akan membuat kita sukar untuk menyelesaikan. Dalam usaha untuk membantu bahagian rantaian pengagihan dalam industri, tesis ini akan memperkenalkan kaedah baru untuk menyelesaikan masalah proses membuat keputusan dalam rantaian pengagihan. Kaedah ini tidak digunakan secara meluas dalam Malaysia walaupun kaedah ini telah wujud selama hampir 40 tahun. Tesis ini juga akan mengambil satu syarikat perindustrian sebagai kajian kes untuk membantu mereka menyelesaikan masalah dalam rantaian pemgagihan mereka dengan menggunakan Proses Analisis Hirarki (AHP). Hasil daripada kajian kes menunjukkan bahawa pendekatan ini mampu untuk menilai serta membuat keputusan yang wajar dan boleh digunakan untuk menyelesaikan masalah lain. Kajian kes ini akan menjadi contoh kepada industri lain untuk mengamalkan Proses Analisis Hirarki (AHP).

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LIST OF ABBREVIATION

AHP	-	Analytical Hierarchy Process
PV	-	Priority Value
BAL	-	Bio artificial Liver
QA	-	Quality Assurance
QC	-	Quality Control
MLT	-	Microbial Limit Test
GMP	-	Good Manufacturing Practice
ISO	-	International Organization for Standard
HPRD	-	High Performance Regulator Detector
STQRM	-	Standard Quality of Raw Material
SOP	-	Standard Operating Procedure

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Industries around the world are now all rushing the territory of globalization and specialization. Cooperating with good strategic partners is the sure way to tackle the potential problems arising from competition. Companies can achieve the optimum operating efficiency by working with other companies through communication and specialization, which evolve a new type of relationship and develop supply chain relationship which call supply chain management concept. In chemical process industry, data and information are important resources apart from materials and energy. The effective management for the variety of information resources becomes necessary for better access and sharing of information, which are vital to collaborative product development and integrated manufacturing. This is related to the development of supply chain. Supply chain has been majorly used in industries to increase their own performance. In order to increase the profit, development of the supply chain must be explore. Supply chain is a system of organization which link people, technology, activities, information and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. In detail, supply chain systems, used products may re-enter the supply chain at any point where residual value is recyclable. The major component in supply chain is raw material, supplier, manufacture and costumer. In order to develop or improve the supply chain, analytical hierarchical process has been used to help in decision making determine the alternative or solution in industries supply chain. This based on research by Thomas L. Saaty (2008) who proposed Analytic Hierarchical Process (AHP) is one of the methodological approaches that may be applied to resolve highly complex decision making problems involving multiple scenarios, criteria and actors.

1.2 Problem Statement

Company potential has been a major subject in business plan. In order to increase its potential, one possible improvement is by looking at the company supply chain. Appropriate alternative selection of supply chain would significantly lead to improvement of product. As a result, profit, company potential, management, investors and customer confident towards company will increase. In this case it will use Analytical Hierarchy Process as a tool to solve decision making problem in choose the best alternatives.

1.3 Research Objective

To use Analytical Hierarchy Process as a method of decision making in supply chain management.

1.4 Scope of The Proposed Study

1.4.1 Define supply chain problems in chemical industries.

1.4.2 Develop a decision model for industrial problem.

1.4.3 Apply Analytical Hierarchy Process for supply chain decision making based on real case study from chemicals industries.

1.5 Significance of The Proposed Study

Significance of this research is to improve decision making in supply chain management by using Analytical Hierarchy Process.

CHAPTER 2

LITERATURE REVIEW

2.1 The Definition of Supply Chain

Supply chain has been an important subject in today industries especially chemical. Supply chain play role as subject of improving the product distribution system. Basically, supply chain is a system in organization where they link people, technology, activities, information and resources in moving a product or service from supplier to customer. Supply chain activities means it will transform natural resources, raw materials and components into a finished product that will delivered to the end customer. In detail, supply chain systems, used products may re-enter the supply chain at any point where residual value is recyclable. Lasschuit (2004) identifies that supply chain represents the integrated view across processes which represent a critical concept to drive coherent strategies and to manage an organization around common (end-to-end) performance objectives. Actually, supply refers to giving resources to the other while chain means flow how the resources move. Therefore, supply chain means the flow of raw material to transform into product that linked to the people which is workers and customers, technology which is machine and activities is work or pathway of transformation of raw material. This definition has been strengthen with Zigiaris (2000) defines that the supply chain encompasses all of those activities associated with moving goods from the raw-materials stage through to the end user.

2.2 The Composition of Supply Chain

Based on the definition of the supply chain, the important and major component are people, technology, activities, information and also resources. In 2004, Chopra highlights that supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves. There are many component in supply chain but it can be summarize to four component stated above. People are manufacture and customer’s meanwhile technology is a tool that can be use to transform goods from raw material. Information is a way of communication that is use by manufacture, workers and customers to make the raw material can be realizing in the form of goods. However there are many opinion of researcher about the main component in supply chain for example in (Jian et al., 2010) studies, he identifies that there are seven components to build up sustainable supply chain which includes suppliers, manufacturers, sellers, consumers, the environment, regulation and culture.

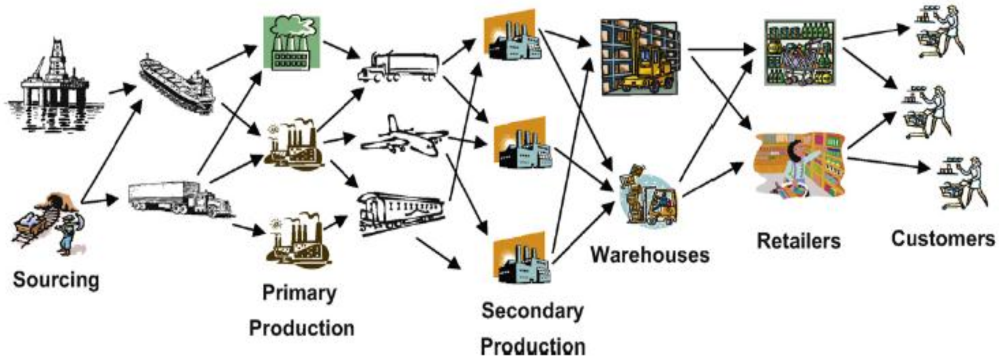

Figure 2.1: Supply Chain Diagram (P. K. Naraharisetti, A. Adhityab, I.A. Karimia, R. Srinivasan, Decision support for resilient enterprises, 2009)

2.3 The Application of Supply Chain in Chemical Industries

Supply chain play as a pathway on delivering goods in industries especially in chemicals. Major goods or raw material in chemicals industries come from chemical. As known, chemicals are very expensive since productions are very challenging. In order to reduce the cost of production in chemicals industries, better plan on supply chain must be start. But the problem is how to decide which process or element in supply chain need to improve. Lasschuit (2004) proposes in his research that in the downstream oil and chemical industry, planning and scheduling are resource-intensive, complex, rolling processes. Decisions are taken at different stages within the supply chain (supply, manufacturing and distribution) and at different levels in the management hierarchy (planning, scheduling and operations). This is because Lasschuit have conducted a research based on the Shell company problem which claims that in their planning and scheduling, he used method of supply chain to improve and make the business go on.

Decision making had been going through every segment or stages in supply chain. Zigiaris (2000) stated an example of improving supply chain through Supply Chain Management application: To Reduce Cycle Time, Kick Those Bad Habits. One of the chief causes of excessive order-to-delivery cycle times is the existence of longstanding "bad habits" that result when companies fail to revise internal processes to reflect market changes. The existence of separate, independent departments tends to perpetuate these inefficient practices. Taking the supply-chain management view, on the other hand, helps companies identify the cumulative effects of those individual procedures. Eliminating such bottlenecks improves product availability and speeds delivery to customers--both of which can increase sales and profits.

In order to give the clear view about application of supply chain, the case that face by Consultant R. Michael Donovan in Zigiaris (2000) journal can be a good example. It illustrates the point with the tale of a client that manufactures a made-to-order machine part. Average order-to-delivery time varied between six and nine weeks. As a result, the manufacturer was losing business to "replicators" that could produce low-quality "knockoff" versions in just three weeks. Donovan and his colleagues analyzed the manufacturer's entire supply chain, from order entry and raw-materials supply all the way to final delivery. They found problems at every step of the way: Handwritten orders were being rekeyed into the materials-planning system on weekends, which meant that some orders were sitting around unprocessed for an entire week. On Monday mornings, production control would be overwhelmed with a week's worth of orders. It often took them several days to plow through the backlog and issue manufacturing orders. Once those orders had been cut, the engineering department required one week to produce technical drawings. They needed several more days to match up drawings with orders and other documentation. Those information packets then would go to the manufacturing line, where the scheduling system allowed three weeks' time for production. "Orders could be sitting there for almost three weeks before going into production, even though the actual time required to produces an item ranged from a few hours to one full day," Donovan recalls. The solution Supply Chain experts were able to slash order-processing time, including the generation of engineering drawings, from about two and a half weeks to one day. They made some alterations to the manufacturing process to speed up production. While they were cutting waste out of physical processes, the consultants also were finding ways to speed up the flow of information and to improve the accuracy of production orders. Today, materials flow is closely correlated with information flow, and lead times have been cut from an average of six to nine weeks down to fewer than three weeks. The payoff! The payoff has been enormous. Instead of steadily losing market share to the replicators, the manufacturer has doubled sales volumes. It has reaped an added benefit as well: Because quality remains very high, the manufacturer has been able to charge more for its products, generating even greater profits. Donovan proudly notes that this radical change was achieved with technologies the manufacturer already had. "We didn't change the technology, we just changed how it was applied," he says. "The magic is not in the software. Information technology should not be the driver of re-engineering the order-to-delivery process," he concludes. "It should enable you to achieve your objectives."

2.4 The Background of Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process is a method use to help in solving problems in decision making. For example, in industries supply chain, company needs to cut cost of the transport raw materials. Engineer have been study and come out with several solutions but the problems are to choose which method or alternative are the best. This situation call decision making. And to solve problems in decision making, Analytical Hierarchy Process is one of the methods to solve this problem. In the beginning of thesis by Saaty (2008), he writes that Analytical Hierarchy Process is a theory of measurement through pair wise comparison and relies on the judgments of experts to derive priority scales. Based on this author, uses of Analytical Hierarchy Process is very useful and important in decision making to avoid the loss in company's money.

Actually, Analytic Hierarchical Process (AHP) is one of the methodological approaches that may be applied to resolve highly complex decision making problems involving multiple scenarios, criteria and actors (Saaty, 2008). Proposed in the 1970s by Thomas L. Saaty, it constructs a ratio scale associated with the priorities for the various items compared. In (Saaty, 2008) journal, he also mentions that there are four step which to make a decision in an organized way to generate priorities needed to decompose the decision which are :

1. Define the problem and determine the kind of knowledge sought.
2. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).
3. Construct a set of pair wise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.
4. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared. Table below will show the analysis on scale number.

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

Table 2.1 : Scale table

Source : Thomas L. Saaty. (2008). Decision making with the analytic hierarchy process

In the first step conducting AHP, the problems need to be identifying since it is our aim or objective. On the other hand the second step is drawing the structure of the AHP which contain the objective, criteria, sub criteria and also alternative. In order to give a clear view, example from the Thomas L. Saaty (2008) can be as a guide.

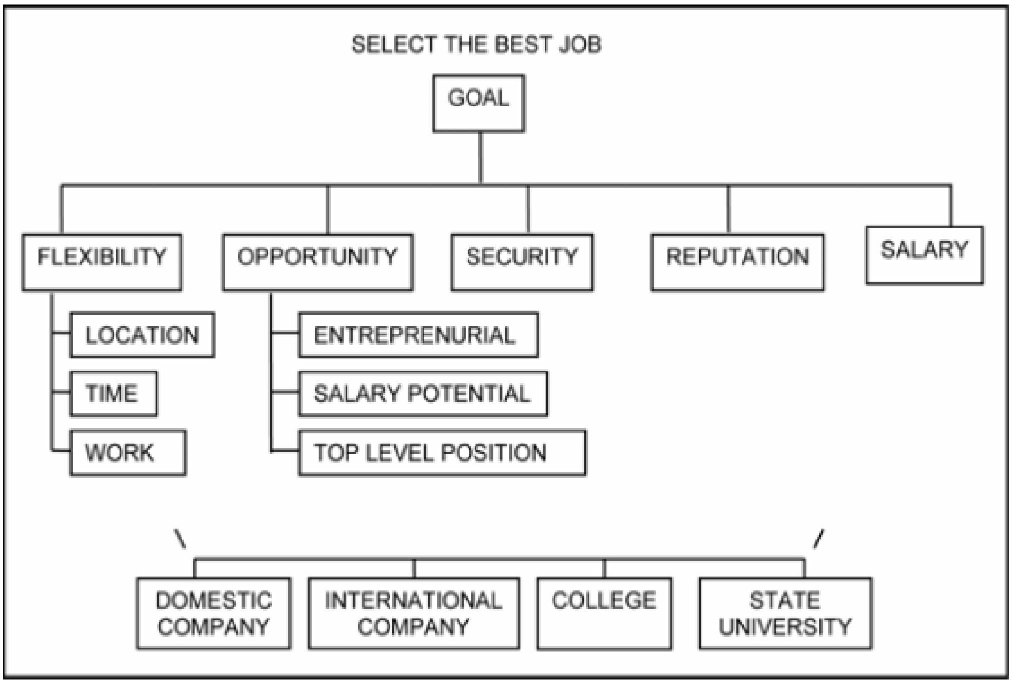

Table 2.2 : selecting best job

Source : Thomas L. Saaty. (2008). Decision making with the analytic hierarchy process

In third step, constructions a set of pairwise comparison matrices need to be draw. There will be 12 pairwise comparison matrices in all which is one for the criteria with respect to the goal, which is shown here in Table 2.4.3, two for the subcriteria, the first of which for the subcriteria under flexibility: location, time and work, that is given in Table 2.4.4 and one for the subcriteria under opportunity that is not shown here. Then, there are nine comparison matrices for the four alternatives with respect to all the 'covering criteria', the lowest level criteria or subcriteria connected to the alternatives. The 9 covering criteria are: flexibility of location, time and work, entrepreneurial company, possibility for salary increases and a top-level position, job security, reputation and salary. The first six are subcriteria in the second level and the last three are criteria from the first level. In order to measure the ranking, we measure by using priorities. The priorities can be calculated as below diagram.

Goal	flexibility	opportunities	Security	reputation	salary	Present value
flexibility	1	1/4	1/6	1/4	1/8	0.3
opportunities	4	1	1/3	3	1/7	0.2
security	6	3	1	4	1/2	0.1
reputation	4	1/3	¼	1	1/7	0.2
salary	8	7	2	7	1	0.2

1. Sum of the values in each column of the pairwise comparison matrix.

$$\begin{vmatrix} 1 & 1/4 & 1/6 & 1/4 & 1/8 \\ 4 & 1 & 1/3 & 3 & 1/7 \\ 6 & 3 & 1 & 4 & 1/2 \\ 4 & 1/3 & 1/4 & 1 & 1/7 \\ 8 & 7 & 2 & 7 & 1 \end{vmatrix} \qquad \text{Column sum} = \begin{vmatrix} 23 & 11.58 & 3.75 & 15.25 & 1.91 \end{vmatrix}$$

2. Divide each element in a column by the sum of its respective column. The resultant matrix is referred to as the normalized pairwise comparison matrix.

$$\begin{vmatrix} 1/23=0.0435 & (1/4)/11.58=0.0216 & (1/6)/3.75=0.0444 & (1/4)/15.25=0.0164 & (1/8)/1.91=0.0654 \\ 4 & 1 & 1/3 & 3 & 1/7 \\ 6 & 3 & 1 & 4 & 1/2 \\ 4 & 1/3 & 1/4 & 1 & 1/7 \\ 8 & 7 & 2 & 7 & 1 \end{vmatrix}$$

3. Add the elements in each row of the normalized pairwise comparison matrix, and divide the sum by the n elements in the row. These final numbers provide an estimate of the relative priorities for the elements being compared with respect to its upper level criterion.

$$\begin{vmatrix} 0.0435 & 0.0216 & 0.0444 & 0.0164 & 0.0654 \\ 0.1738 & 0.0864 & 0.0889 & 0.1967 & 0.0748 \\ 0.2609 & 0.2591 & 0.2667 & 0.2623 & 0.2618 \\ 0.1739 & 0.0288 & 0.0667 & 0.0656 & 0.0748 \\ 0.3478 & 0.6045 & 0.5333 & 0.4590 & 0.5236 \end{vmatrix}$$

$$\text{Row sum} = \begin{vmatrix} 0.1913 \\ 0.6206 \\ 1.3108 \\ 0.4098 \\ 2.4682 \end{vmatrix}$$

$$\text{Eigen vectors} = \begin{vmatrix} 0.1913/(0.1913+0.6206+1.3108+0.4098+2.4682) = 0.0383 \\ 0.6206/5.0007 = 0.1241 \\ 1.3108/5.0007 = 0.2621 \\ 0.4098/5.0007 = 0.0819 \\ 2.4682/5.0007 = 0.4936 \end{vmatrix}$$

The resulting priority value, PV in this example for the second level, states that the salary 49%, security 26%, opportunities 12%, reputation 8% and flexibility influence 3%.

We only show one of these 9 matrices comparing the alternatives with respect to potential increase in salary in Table 2.4.5.

	Flexibility	*Opportunities*	*Security*	*Reputation*	*Salary*	*Priorities*
Flexibility	1	1/4	1/6	1/4	1/8	0.036
Opportunities	4	1	1/3	3	1/7	0.122
Security	6	3	1	4	1/2	0.262
Reputation	4	1/3	1/4	1	1/7	0.075
Salary	8	7	2	7	1	0.506

. Table 2.3: Pairwise comparison matrix of the main criteria with respect to the Goal

Source: Thomas L. Saaty. (2008). Decision making with the analytic hierarchy process

	Location	*Time*	*Work*	*Priorities*
Location	1	1/3	1/6	0.091
Time	3	1	1/4	0.218
Work	6	4	1	0.691

Table 2.4: Pairwise comparison matrix for the sub criteria with respect to flexibility

Source: Thomas L. Saaty. (2008). Decision making with the analytic hierarchy process

	Domestic Co	*Int'l Co*	*College*	*State Univ.*	*Priorities*
Domestic company	1	4	3	6	0.555
Int'l company	1/4	1	3	5	0.258
College	1/3	1/3	1	2	0.124
State University	1/6	1/5	1/2	1	0.064

Table 2.5: Pairwise comparison matrix for the alternatives with respect to potential Increase in salary

Source: Thomas L. Saaty. (2008). Decision making with the analytic hierarchy process

Based on the example that have shown by Thomas L. Saaty (2008) journal, in Table 2.4.3, the criteria listed on the left are one by one compared with each criterion listed on top as to which one is more important with respect to the goal of selecting a best job. In Table 2.4.4, the sub criteria on the left are compared with the sub criteria on top as to their importance with respect to flexibility. In Table 2.4.5, the alternatives on the left are compared with those on top with respect to relative preference for potential increase in salary. The criteria priorities in Table 2.4.3 are weighed by the priority of their parent criterion flexibility (0.036) to obtain their global priority. The priorities for each matrix are obtained as they were from the matrix of comparisons. In Table 2.4.6, the rankings of the alternatives are given against the nine covering criteria (only one of the matrices leading to the rankings was given, in Table 2.4.5). We need to multiply each ranking by the priority of its criterion or sub criterion and add the resulting weighs for each alternative to get its final priority. We call this part of the process, synthesis which is given in table 2.4.6.

Criteria Subcriteria	Flexibility 0.036			Future opportunity 0.122			Security 0.262	Reputation 0.075	Salary	Overall Priority
Global weights (criteria × subcriteria)	Location 0.091	Time 0.218	Work 0.691	Entrepreneurial 0.105	Salary increases 0.637	Top level position 0.258	0.262	0.075	0.506	
Domestic Company	0.003	0.008	0.025	0.013	0.078	0.032	0.225	0.064	0.124	0.193
Internatn'l Company	0.295	0.084	0.062	0.090	0.555	0.591	0.054	0.101	0.547	0.333
College	0.496	0.055	0.115	0.061	0.258	0.274	0.095	0.247	0.289	0.214
State University	0.131	0.285	0.249	0.239	0.124	0.083	0.626	0.588	0.039	0.262

Table 2.6: Synthesizing to obtain the final results

Source: Thomas L. Saaty. (2008). Decision making with the analytic hierarchy process

The last step in conducting the AHP is use the priorities obtained from the comparisons to weigh the priorities in the level immediately and this process of weighing and adding continues until the final priorities of the alternatives in the bottom most level are obtained. The overall priorities for the alternative jobs given on the far right of the lower piece of Table 2.4.6, are the sums across each row for the alternatives. Note that they sum to 1. These priorities may also be expressed in the ideal form by dividing each priority by the largest one, 0.333 for International Company, as given in Table 2.4.7. The effect is to make this alternative the ideal one with the others getting their proportionate value. One may then interpret the results to mean that a State University job is about 78% as good as one with an International Company and so on.

Name	*Normalised priorities*	*Idealised priorities*
Domestic Company	0.193	0.579
Internatn'l Company	0.333	1.000
College	0.214	0.643
State University	0.262	0.785

Table 2.7: Final results shown as normalized priorities and idealized priorities

Source: Thomas L. Saaty. (2008). Decision making with the analytic hierarchy process

2.5 The Application of Analytical Hierarchy Process (AHP) in Chemical Industries

Analytical Hierarchy Process is very important towards industrial problem. It based on the definition of the analytical hierarchy process which provides the method to choose alternative for the problem based on the hierarchy. Based on the definition, it can be say that having a lot of the application towards the industries. For example, from the journal written by Takeshi Omasa (2004) said that in the field of the chemical engineering, the AHP or analytical hierarchy process has been widely use for the engineering problem of selecting a chemical laboratory reactor. In chemical engineering, the choosing reactors are very important since to produce correct, sustainable and high efficiency of conversion. In order to choose the reactor, it needs to consider many factors to fulfill the requirement of process. Based on that, proper decision making has conducted to choose the alternative of the problem and using AHP this decision making will become easier. Takeshi Omasa (2004) have conducted a research on developing a method of human oriented evaluation in tissue engineering and regenerative medicine. He use the analytical hierarchy process (AHP) to evaluate the tissue engineering reactors. In order to evaluate it, he have to deal with five criteria which are safety, scalability, cell growth environment, mimicking native liver function and handling. Based on his journal, result come out by using the AHP method are he can successfully ranked the Bio artificial Liver (BAL) system as a bridge use in liver transplantation the attempt at decision making based on human oriented evaluation.

Besides choosing the reactor, Analytical Hierarchy Process also helps in measure the cost scale of industries project depend on the requirement. Abdul Aziz (1996) proposed in his journal that AHP can help or assist such industrial investment companies in the design of a specific scale to measure the initial viability of industrial projects. This means that AHP can be used in the scaling or designing the industrial project based on their requirement and AHP will assist by providing the best alternative based on the factor that influence the changes of the project. Abdul Aziz (1996) in his journal has applied the uses of AHP. He actually has conducted research on measure the initial viability of industrial projects. He uses AHP to help or assist him in decision making process which deals with qualitative and quantitative aspect in problems. The result from this research based on the ranking will help management in the efficient allocation of the company's resources. The application of this proposed study has been illustrated through a data to rank industrial project at an Inter-Arab Gulf industrial investment company.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology Flow Chart

In this chapter, we will discuss about the methodology or case study flow on Analytical Hierarchy Process. There are six steps in this methodology which each step represent towards flow of case study.