ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

The Analytical Hierarchy Process to Prioritization Production Factors

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ARTICLE INFO

Article history:
Received 10 October 2015
Accepted 30 November 2015
Available online 31 December 2015

Keywords:
Analytical Hierarchy Process,
Decision Making,
Production Planning.

ABSTRACT

Background: This paper discusses the factors of production that affected the production quantity. These factors have many problems and effect for production planning, so that must be solved immediately. Because to keep the production stable or more increase, companies have to rank the production factor problems to know which one more importance and should be resolved first. However, to choose the priority should not be based on intuition but need through understanding of the decision problem and the process to prioritize the factor. Therefore, This problem can be viewed as a multi criteria decision making problem. Because of that, this study proposes Analytical Hierarchy Process (AHP) method for solving this problem. AHP is method for multi criteria decision making which is using quantitative and qualitative approach. **Objective:** This study aims is to facilitate the manager of production for analysis the problems and making the right decision with prioritization the problem (production factors). **The results:** the priority factor that influences the production quantity is the internal factor. The ranking factor are capital, labour, raw materials and technology and machinery. **Conclusion:** The result of this study gives more clear information about factor production, which is so problematic that the company easier to make a decision and the AHP method is suitable for resolving the production problem.

To Cite This Article: Abdul Talib Bon, Silvia Firda Utami, Sukono., The Analytical Hierarchy Process to Prioritization Production Factors. ***Aust. J. Basic & Appl. Sci.,*** *9(37): 178-184, 2015*

INTRODUCTION

The production planning as one of the most important parts of business management especially operation management (Denisa, 2012). Good production planning is highly preferred by each manufacturing company because by doing so the customer requests can be fulfilled optimally. Many aspects to note in production planning, such as companies have to react to dynamic market conditions and rising customers demand for shorter delivery, lower prices, and better quality and services (Denisa, 2012). When changing market environment causes a rise in complexity as well as intensity of production planning, efficient planning system is often a key weapon for remaining competitive. The complexity and intensity of production planning is not only come from the market environment but also come from many factor of production that involve capital, labor, technology, machine etc. (Griffin, 2006; Drucker, 1974; Barro, 1996). This factor is very influential in the success of a production company. All the factors have linkages with each other and cannot be separated. For example, when one of them is problematic, it will give effect to the other factors. Then, if this occurs a production manager (Decision Maker) will have difficulty to handle it and choose a factor which should be prioritized for completed first. The process of decision making in production (operation management) has become more complex (Subramanian *et al.*, 2012). The prioritization of the production factors is very difficult and this problem is a multi-criteria decision making (MCDM) problem.

To assist decision makers in making decisions in the company, it is necessary to have an effective and efficient model that can help resolve those problems. This has required the use of Multi-Criteria Decision-Making (MCDM) methods for making effective decisions that satisfy all the relevant criteria at various levels. Multi-criteria decision-making (MCDM) method are helpful in solving complex problems that cannot be solved straightforwardly. The fundamental rule of using MCDM is that the solution should be based on multiple criteria. Because the issues related to production factors are becoming more complex, it seems to be difficult to handle all issues pertaining to production factors in a single set of procedures. Among the various MCDM

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techniques proposed, the Analytic Hierarchy Process (AHP) proposed by Saaty (1980) is very popular and has been applied in wide variety of problems such as alternative evaluation and selection, priority and ranking, benefit-cost analysis, resource allocation, quality management (Lin, 2012). In addition, there is a vast literature on the applications of AHP with more than 1300 papers and 100 doctoral dissertations (Subramanian *et al*, 2012; Forman, 2001). In that method, pairwise comparisons are performed by the decision-maker (DM) and then the pairwise comparison matrix and the eigenvector are derived to specify the weights of each parameter in the problem. The weights guide the DM in choosing the superior alternative or criteria (Javad, 2014). The general aim of the analytic hierarchy process (AHP) is to show an assessment of the best decision, which includes certain judgments incoherencies when subjective opinions are adopted, due to the fact that human judgments is not always consistent (González-Prida *et al.*, 2014; Moreu, 2012). AHP method establishes a series of scales of comparisons, where inputs can be measured as the price, weight, time, provisioning, etc., or even the subjective opinion on how the satisfaction and preference sentiments can be.

The purpose of this study is to use AHP method for prioritization the factor of production which affected the quantity of production to facilitate the decision maker (DM) when analysis the problem occurred and making the good decision.

Case Study:

This research is made in a company CPO in Malaysia. Call it the X Company which produces CPO as one of its flagship products. The company's production planning is fairly simple, but a bit complex because of the characteristics of the raw materials (FFB) are special so it takes a special treatment. The complex production planning company X is incremented when the presence of a troubled production factor, for example the amount of raw materials that are slightly damaged, the machine and the number of workers who are lacking. These problems will directly give effect on the decrease in the number of the production of CPO. The company's production management team X especially the production Manager will be responsible for resolving all problems occurred in order to avoid the occurrence of losses at the company. The actions and decisions taken must be quick and precise. The difficulty they experienced was when about to choose problems (factor of production) which is more important and more priority to be resolved. Therefore the research was created to simplify the company's production manager X for a decision by finding the troubled production priority factor or can be said the research will grow to make rank from the factor of production from most large influence to the most small.

Production planning in crude palm oil become very important part of production management company X, because companies have to react to dynamic market conditions and rising customers demand for shorter delivery, lower prices, and better quality and services. However, Production includes all activities not only includes the manufacture of goods that can be viewed by using the factors of production. Activities that occur in the production process include changes in the shape, place and time.

According to Ngige Chigbo D. (2014), the classical economists from Karl Marx (1818-1883), he identified land, labour, and capital as a factor of production (Drucker, 1974). And then, J. B. Say (1767-1832) add entrepreneurship as one of the factors of production. Along with the development of the times, the technology is considered to be a production factor. Barro (1996) argues that the factors of production include government policies, human capital, and the diffusion of technology. And according to Griffiin R. (2006), production factors can be classified into labour, capital, physical resources, entrepreneur, and information resources. In company crude palm oil. Based on the results of the literature study and combined with the results of the interview with the company's production management team then it is making a hierarchical structure factor affecting the decrease in the number of the production of CPO as follows:

Research Methodology:

AHP, developed by Thomas. L. Saaty. This method is a multi-criteria and multi-objective decision making process that proven and widely used method to solve these types of decision problems in diverse fields (Saaty, 1980; Gurumurthy *et al.*, 2012). Early in the 1970s, Saaty developed an ingenious approach to help decision makers in modelling complex problems in a simple way, while his working on studies for the Department of Defense and the National Science Foundation. His published textbook, entitled The Analytical Hierarchy Process (Saaty, 1980) and his release of the PC-based software, entitled “Expert Choice” in 1983 (Expert Choice, 2002) helped popularize the process amongst operations research practitioners.

Since the publication of the first papers, books, and software, AHP has been used by decision makers all over the world to model problems in more than 30 diverse areas including resource allocation, strategic planning, and public policy. It has been used to rank, select, evaluate, and benchmark a wide variety of decision alternatives (Garg, *et al.*, 2012; Goyal *et al.*, 2015). A wide range of AHP applications has been catalogued, categorized, and annotated in edited volumes and books [(Saaty and Vargas, 2000), in journal articles (Forman, 2001), and on web sites (www. expertchoice.com/testimonials/default.htm).

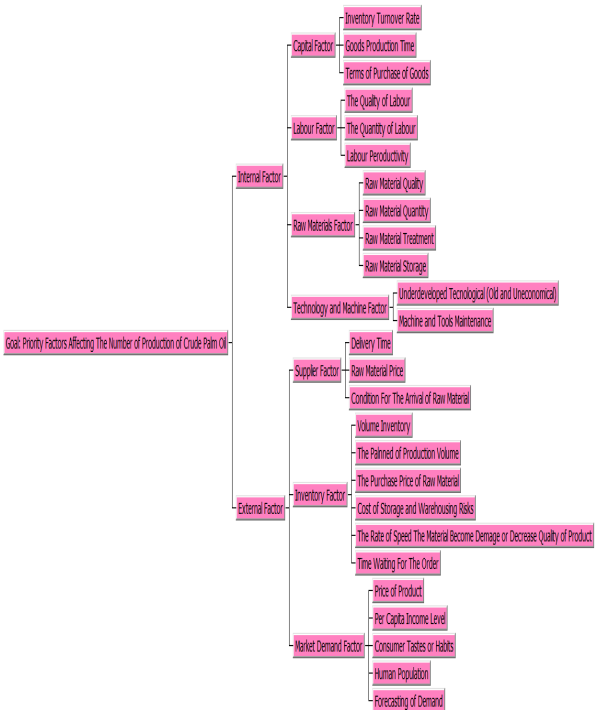

Fig. 1: Structure Hierarchical

Furthermore, AHP has been used by organizations in both the public and private sectors to deal with complex problems. An international symposium on AHP has been held every few years since the late 1980s (see www.isahp2003.net). The empirical evidence of AHP practice has been developed since the late 1970s. It clearly shows that AHP has had a significant impact on the practice of decision-making.

AHP is a mathematical decision-making method introduces by Saaty (1980) to solve complex decision-making problems containing uncertainty and complexity (Goyal *et al.*, 2015). AHP helps in decomposing the complex problem into a hierarchy of simple factors and sub-factors and make their measurement easier with the help of a comparative analysis Saaty (1980). AHP is an approach in which decision-making problems are hierarchically constructed, and attribute weights are derived indirectly from relative importance scores in pairwise comparisons Saaty (1980). This research method is applied in uncertainty situations to solve multi-objective or multi-criteria decision-making problems. When faced with complex problems, interrelated influential factors usually exist in assessment criteria. The decision maker needs to make a decision based on the assessment of the importance of these factors. The general aim of the analytic hierarchy process (AHP) is to show an assessment of the best decision, which includes certain judgment incoherencies when subjective opinions are adopted, due to the fact that human judgment is not always consistent (González-Prida *et al.*, 2014; Moreu, 2012). Then, the important feature of this method is a check of the consistency in the expert decisions in developing the comparison matrix (Saaty, 1994). It entertains both qualitative and quantitative factors. It can handle a huge number of criteria and sub-criteria effectively (Goyal *et al.*, 2015; Bevilacqua *et al.*, 2000). It also provides a reasonably significant structure of the problem with the priority weights.

The questionnaires is AHP application which designed and proposed by Saaty for decision makers to make preference decisions and transformed the complex decision system into a concise element hierarchy. It used nominal scale to conduct pairwise comparison on the importance of every index problems to quantify it and establish the Pairwise Comparison Matrix. Then, it derived the eigenvector of the matrix and the eigenvector represents the priority values of the elements. When applying AHP in solving complex problems, it approximately can be divided into five steps (Saaty, 1980):

1. Define the problem and elements:

Looking for the cause of the problem by considering various aspects and factors which affected it. Many ways that can be done to find problems such as in this case, the production manager can also learn problem with hold meetings weekly or monthly. After the problem is found then the next decisive factor - factors that affected it, list all the deals and then analysis. In other words, take the factors that might affect the problems into account and then, analyze and list the impact factors according to past theories and experiences or through group brainstorming (Chen, 2014).

2. Construct a hierarchical structure:

Hierarchy development is usually based on previous studies and empirical experience. In hierarchy, the top level is *goal* or overall objective followed by *criteria*, down further to *sub-criteria* and finally to the *alternatives* from which the choice is to be made. Then elements of hierarchy are grouped in clusters according to homogeneity. A level consists of one or more homogeneous clusters (Saaty, 1987a).

In constructing an overall hierarchical structure, it can form a multiple hierarchical relationship starting from goals, sub-objectives, forces that affects the sub-objectives, people that affects the forces, the goals and policies of the people, strategies and last, the outcomes of these strategies. The construction of the hierarchy can adopt the top to-bottom approach and further derive the levels one-by-one or it can also adopt the bottom-to-top approach where it starts from the plan level and gradually traces back to the goal level (Chen, 2014).

In deciding the number of levels, it should at least have three levels depending on the complexity of the analysis of the problems. In general, when using levels to analyze problems, the highest level is usually used to analyze the interactions between levels and is not analyze directly from the factors of each level. The factors that affect the problem should be decomposed into clusters and these clusters should be further divided into sub-clusters to create the whole hierarchical structure level by level (Chen, 2014).

In analyzing each cluster, the highest level represents the ultimate goal of the evaluation and the elements that have similar importance should be placed on the same level. Each level should not have more than seven clusters. According to the suggestion of Saaty, it is better that every layer should have a maximum of seven cluster and layers that exceed the limit can further be subdivided so not to affect the consistency. It's better if each element is independent. If dependency can be the first, analyze independency first then dependency after and then process it together. The elements of the bottom layer are the alternatives (Chen, 2014).

3. Establish assessment scale:

After completing the hierarchical structure, assessment can be conducted. The task of AHP is to evaluate the element on every layer based on the upper layer to serve as the basis for evaluation for the elements in the lower layers. In other words, the two elements in a layer use the element of the layer above it as the standard and separately evaluating the corresponding contribution and importance of the two elements on the standard. This process is to decompose the complex problem into pairwise comparison to reduce the burden of the evaluator in thinking and focus on the relationship of the two elements (Chen, 2014). With the help of experts, the decision matrix is developed according to Saaty (1994) 9-point scale, as shown in Table I.

Table 1: Saaty Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgement slightly favor one activity over another
5	Essential or strong importance	Experience and judgement strongly favor one activity over another
7	Demonstrated importance	An Activity is strongly favored and its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate value between the two adjcent judgments	when comromise is needed
Resiprocals of above nonzero numbers	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*. Then j has the reciprocal value when compared with *i*.	A reasonable assumption
Rationals	Rational arising from the scale	If consistency were to be forced by obtaining *n* numerical value to span the matrix

The evaluation scale of AHP can be basically divided into five levels, least strong, less strong, strong, very strong, strongest and used 1, 3, 5, 7, 9 as the measurement value in the nominal scale. There are four scales in between the five basic scale where 2, 4, 6, 8 are used as the measurement values.

Fundamental 9-point scale (Table-1) represents the intensities of judgment used to provide estimates of the ratios in the pairwise comparison matrices. It is assumed that the elements of comparison are of the same order of magnitude, i.e. their relative weights do not differ by more than 9. The fundamental scale is validated for effectiveness through many applications and theoretical justification (Saaty & Vegas, 2001). When elements of a comparison are very close to each other than fraction scale can be

used like 1.1, 1.2, …1.9 or still finer scale can be used depending upon application (Saaty, 1990a).

4. The next step is to perform the pairwise comparison of one criterion over another with the help of decision matrix.:

Pairwise comparison reduces conceptual complexity of the problem. Each element is compared with other elements of the same cluster to decide their relative importance on '1 to 9' scale. Larger is the scale, the larger will be the differences between the criteria levels. The number of judgments needed for a particular matrix of order n, which is equal to the number of one to one comparisons between elements, is n×(n - 1)/2 because the diagonal elements are all equal to unity, and the lower diagonal is always reciprocal (Saaty, 1987a). Pairwise comparisons of elements concentrate just on judgment without any concern for other elements. This is why paired comparisons in combination with the hierarchical structure are so useful in deriving measurement (Saaty, 1990a). After obtaining the pairwise comparison matrix, compute for the eigenvector of the elements of every level.

The eigenvalue solution commonly used in the numerical analysis is used to find the eigenvector.

Saaty suggested the use of Eigen vector method to derive the vector of priorities from the comparison matrix. The departure of the principal eigenvalue of the matrix of judgments from the order of that matrix *n*, is a measure of its inconsistency. This method identifies the judgments, which require revision to improve the consistency score (Saaty, 1990b).

The AHP theory assures that the weights concerning the comparison matrix are the elements of the normalized eigenvector associated to the maximum eigenvalue of that matrix. Moreover, if the comparison matrix is consistent, it is possible to demonstrate that the matrix has only one positive eigenvalue λ_{max}=n and all the other n-1 eigenvalues are equal to zero. If the comparison matrix is not consistent, provided it is not too much inconsistent, again it produces a positive maximum eigenvalue and a corresponding normalized eigenvector. Since a consistent matrix has λ_{max}=n, the inconsistency of a given comparison matrix can be quantified by evaluating the so called ''Consistency Index''

The consistence ratio (CR) is used to measure the overall consistency of comparison matrix. If CR≤ 0.1, the consistency of the matrix satisfies the requirement. Then, the consistency index (CI) is calculated as, λ_{max} is the principal eigenvalue of matrix *A* where *A* may not be consistent, n is the number of elements in the comparison matrix and CI is the negative average of the other roots of the characteristic polynomial of *A*. This value is compared with the same index obtained as an average over a large number of reciprocal matrices of the same order whose entries are random (Saaty, 1990a; Saaty 1987b). Saaty has suggested random consistency index as shown in Table-2. The ratio of CI to RI is known as Consistency Ratio (CR). If this ratio is less than 10% then the decision is accepted as it is. Otherwise, the judgment has to be revised to improve consistency (Saaty 1987a).

Table 2: Random Index Value (RI) (Saaty, 1991)

Size of Matrix	Random Consistency
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

5. Synthesizing ratio judgments:

The judging process may involve single or multiple people. If multiple people are involved in decision process then judgments are synthesized into a single judgment, which must satisfy the reciprocal property for the group. This implies that the consolidated judgment should be calculated using geometric mean (Aczél & Saaty, 1983; Mulik *et al.,* 2008).

Discussion And Conclusion:

This research uses a software expert choice 11 to help determine the priority factor in the production of CPO. A questionnaire was used for data retrieval with spreading to the respondents. The respondents are the company's production management team, which is the decision-maker in the company X. The selected respondent is the person who has expert in the production of the company. The content of the questions in the questionnaire is a comparison of factors at each level of hierarchy that have been made before. After getting the answers of all respondents then next is the normalization of the answers up to form a paired comparison matrix for each level. After getting a pairwise comparison matrix, then the next is determining the eigenvector. This value is the final value that would later become the value that rate ranking factor. From this we can

know which factor is more priority. In addition, to ensure that the results obtained are consistent, then the next step is to test the consistency of the results. The trick is to calculate the value of each CR level. If the value of CR obtained less than 10%, then the results are consistent. As seen in the picture below which shows the value of the eigenvector or the order of priority of each level and the value of consistency:

Table 3: Result Expert Choice 11 for Level II and III.

GOAL	CRITERIA LEVEL II	SUBCRITERIA LEVEL III
Priority Factor Affecting The Number of Crude Palm Oil	Internal Factor: **(0,738)**	Capital Factor (F.a): **(0,518)**
		Labour Factor (F.b): **(0,228)**
		Raw Material Factor (F.c): **(0,133)**
		Technology Machine Factor (F.d): **(0,121)**
	External Factor: **(0,262)**	Suppliers Factor (F.e): **(0,684)**
		Inventory Factor (F.f): **(0,179)**
		Market Demand Factor (F.g): **(0,137)**

From the calculations that have been done, then obtained the main priority factor affecting the decrease in the number of production (Table-3) is, the internal factor. But the details of the internal factor are the factor capital. These factors have eigenvector is high compared to other factors. Factor capital become a priority because this factor with regard to all factors that exist. The capital factor has a very powerful effect when hit by problems. Its influence can make a factor other production factors cannot run smoothly. Therefore company X needs to give greater attention to resolving the problem of capital, and make the capital is a top priority issue that is resolved quickly. In addition to the factor capital, at level III each factor also has a ranking factor as shown in the pictures above. This ranking provides a more detailed information so that it can facilitate the team manager of the production company X to make a decision. And again in more detail in the following order of priority factors exist at level IV:

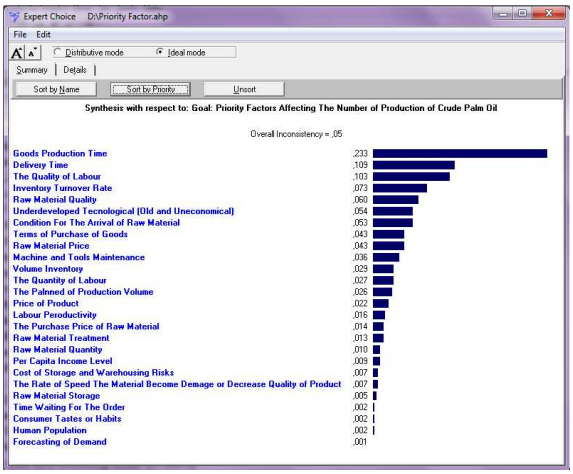

Fig. 2: Result for Level IV

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