OPTIMAL COMBINED LOAD FORECAST BASED ON MULTI-CRITERIA DECISION MAKING METHODS

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CHAPTER 1

INTRODUCTION

1.1. project Background

A power system serves one function and that is to supply customers, both large and small, with electrical energy as economically and as reliability as possible. Another responsibility of power utilities is to recognize the needs of their customers (Demand) and supply the necessary energies. Accurate forecasting of energy requirement for future development of the country is one of the most important factors of energy management. Adequacy of energy is the main factor for the development of a country.

Energy requirement depends on number of variables, some of them which are cardinal to the energy consumption and addressed here are population, number of electricity consumers, per capita electricity consumption, peak electricity demand, gross domestic product and annual electricity consumption of the country. Unfortunately, it is difficult to forecast load demand accurately over a planning period of several years. This fact is due to the uncertain nature of the forecasting process. There are a large number of influential that characterize and directly or indirectly affect the underlying forecasting process, all of them uncertain and uncontrollable. Many load forecasting problems in practical usually are solved by experts with the judgment and experience. Therefore it can't represent the innate character of the forecasting problem completely too only make use of the mathematics programming. In hard methods it is be devoid of the analysis, judgment and control to forecasts and results.

In this paper, soft method is presented to carry out combined forecast for the electrical power load demand, through integrating different forecast methods, combining the mathematics method and expert's experience and using the intellection of the decision maker sufficiently. The combine load forecast problem is settled to the decision-making problem through combining the quantitative calculation and qualitative analysis. The structure of hierarchy process for the combined load forecast is established. Multi-criteria factors are counted. Expert's judgments are combined.

The Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is adopted in the long-middle term electric power load combined forecast. The soft method of electric power load combined forecast is account for not only the highest fitting accuracy (HFA), but also suitability of methods to actual state (SMS) and believability of forecasting results (BFR) as the criteria of decision adjudicate. HFA is same as the object of hard methods. Different hard forecast methods and their different results are analyzed synthetically. The forecasting load value of electricity power MWH and MW in further years can be recommended according to the synthetic analysis

1.2. Problem Statement

According to the statistics provided by TNB as shown in Figure 1.1 [10], the demand of the electric power was increasing year by year from 2005 to 2008. Figure 1.1 shows the total electricity sales of Tenaga Nasional Sdn.Bhd (TNB) in the year 2005 to 2008. The total electricity sales increased 5.34% from 2005 to 2006, 5.65% from 2006 to 2007 and 3.85% from 2007 to 2008. The sales increased 15.58% within three years of total electricity sales.

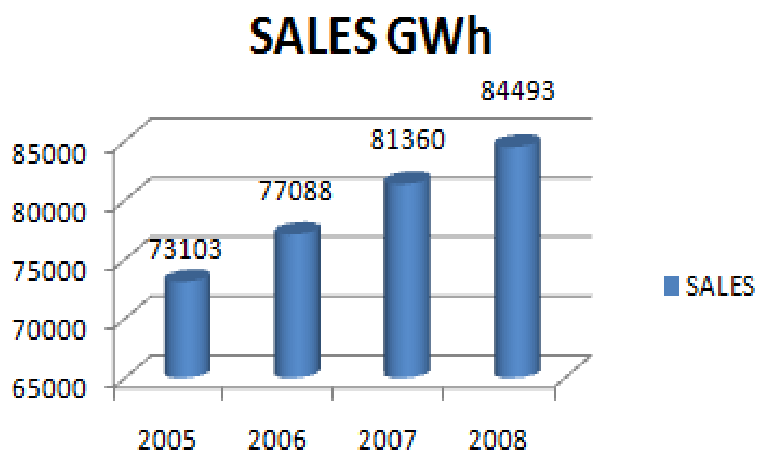

Figure 1.1: The total electricity sales (GWh) of TNB [7]

The electric power demand in Peninsular Malaysia has steadily increased in the past four years. This trend is certain to continue in future. The electrical load is the power that an electrical utility needs to supply in order to meet the demands of its customers. Electricity load forecasting is thus an important topic, since accurate forecasts can avoid wasting energy and prevent system failure. The forecast results obtained from the different forecast methods may very different. Which method or which forecast result can be agreed upon? For the more accurate and satisfactory forecast result can be obtained, many forecasting are integrated and forms the combined forecasting method. This paper present the analyzing of soft method such as decision making analyses to solve load forecast in power system demand that are unstructured problems of multi-factors. The combined forecasting problem is treated as multihierarchies and multi-factors evaluation by composing qualitative analyses and quantitative calculation. In addition, the experiences and judgments of experts will be collected to implement judgment matrices in group decision making.

1.3. Project objectives

There are three objectives for this project:

a) To determine which the existing forecast method more accurate and satisfactory by using multi criteria decision making system.

b) To implement multi-criteria decision-making methods such as AHP, fuzzy AHP and TOPSIS in the power demand system

c) To determine the effectiveness of multi-criteria decision making methods in the power demand system

1.4. Scope project

This project is primarily concerned with the optimal combine load forecasting base on multi-criteria decision method. The scope of this project work includes the following;

a) Electrical power demand in Sabah

b) Develop the three stages of hierarchy structure:

   i. Goal which is the Satisfactory an accurate of electrical power Load forecast

   ii. Criteria Hierarchy may be a factor that affects the total goal. Using soft method which is combining the mathematics method and expert experience

   iii. Candidate Scheme Hierarchy which is a set of composed hard forecast methods and their forecast results

c) Comparison of simulation and experimental results. The analysis will focus on to calculate the weight vector for each load forecast because it reflects the important degree for each forecast methods and results, which is relative to the accuracy load forecast.

CHAPTER 2

LITERATURE REVIEW

2.1 Load Forecast

Accurate models for electric power load forecasting are essential to the operation and planning of a utility company. Load forecasting helps an electric utility to make important decisions including decisions on purchasing and generating electric power, load switching, and infrastructure development. Load forecasts are extremely important for energy suppliers, ISOs, financial institutions, and other participants in electric energy generation, transmission, distribution, and markets [6]. From the Table 2.1 below load forecasts can be divided into four categories:

Load forecasting	Period	Importance
Long-term	One year to ten Years	• To calculate and to allocate the required future capacity. • To plan for new power stations to face customer requirements. • Plays an essential role to determine future budget.

Medium-term	One week to few months	• Fuel allocation and maintenance schedules.
Short-term	One hour to a week	• Accurate for power system operation. • To evaluate economic dispatch, hydrothermal co-ordination, unit commitment, transaction. • To analysis system security among other mandatory function.
Very short-term	One minute to an hour	• Energy management systems (EMS).

Table 2.1: Load Forecast categories

To improve forecasting accuracy, combine forecasts derived from methods that differ substantially and draw from different sources of information. Combining is useful to the extent that each forecast contains different yet valid information. The key principles for combining forecasts are to use [3]

- Different methods or data or both,
- Forecasts from at least five methods when possible,
- Formal procedures for combining,
- Equal weights when facing high uncertainty,
- Trimmed means,
- Weights based on evidence of prior accuracy,
- Weights based on track records, if the evidence is strong, and
- Weights based on good domain knowledge.

Combining is most useful when there are [3]

- Uncertainty as to the selection of the most accurate forecasting method,
- Uncertainty associated with the forecasting situation, and
- A high cost for large forecast errors.

Compared to the typical component forecast, the combined forecast is never less accurate. Usually it is much more accurate. Also under ideal conditions, the combined forecasts were often more accurate than the best of the components. Combined forecast can be better than the best but no worse than the average. That is useful for forecasters.

2.2 Comparison Methodologies of Load Forecast.

Methodology	Advantages	Disadvantages
Time series	• Easy to implement – requires only the historical data of the variable to be projected	• Accuracy depends solely on the stability of historical trends
Regression	• Better portrays the changes in demand through its various drivers (GDP, price, etc)	• Requires more resources & knowledge of the underlying relationship of the independent & dependent variables
Elasticity	• Easy to implement, incorporates the development process of the country	• Requires judgmental input • Lack of statistical test to determine accuracy
Intensity	• Sectoral demand linked to economic performance & explained by its drivers (GDP, floor space, etc)	• Absence of price variable • Lack of statistical test to determine accuracy
Load curve	• Helps to understand changes in demand	• Requires more resources & knowledge of the underlying relationship of the independent & dependent variables
End-use	• Better portrays the usage of electricity by the consumers	• Model is data intensive • Requires a detailed knowledge on how & where electricity is utilised

Table 2.2: Comparison Methodologies Load Forecast [10]

2.3 Simplified Work Flow For Middle-Long Term Demand Forecasting

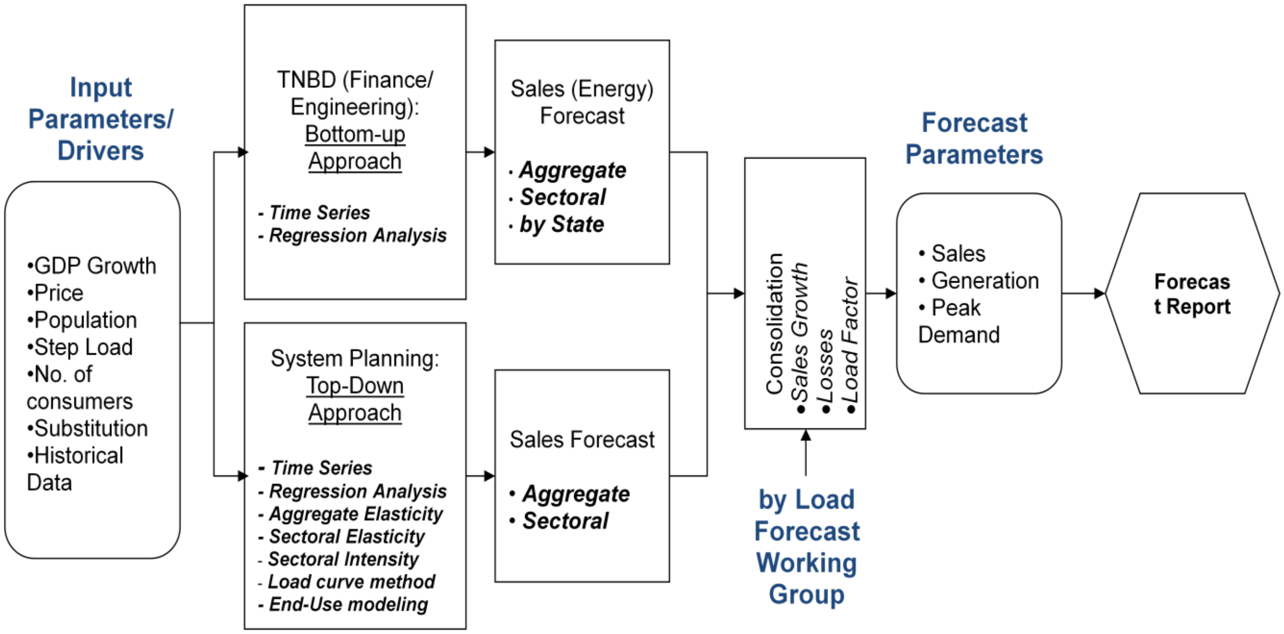

Figure 2.1: Simplified Work Flow for Middle-Long Term Demand Forecasting [10]

Bottom-Up Approach: assesses the demand at micro level e.g. Growth centers/areas (step loads, number of customers).

Top-Down Approach: analyses the demand at macro level e.g. GDP, prices, population, etc.

2.4 AHP

Analytic Hierarchy Process (AHP) is a method developed for creating structured models of multi-criteria decision problems. The method helps to find an alternative which suits best the given needs of the deciding person. Analyzing the set of possible alternatives, the AHP method finds the one with the best rating, based on the structure of the problem and given preferences. Saaty formulated the principles of AHP in late 1970s (Saaty, 1980), and the method has been broadly studied and applied in many cases since the time [4].

The method combines mathematical and psychological aspects, starting with defining the structure of the problem, then quantifying the relative preferences, computing the priorities and finally computing the evaluation of all considered alternatives [4].

- First of all, the multi-criteria decision problem is converted into a hierarchy of sub-problems and every of the sub-problems are then independently analyzed.
- The criteria of the sub-problems in the hierarchy may have very heterogeneous nature; they may be precisely or vaguely defined, with crisp or fuzzy parameters, formal or intuitive, etc.
- The relative preferences of heterogeneous criteria are then quantified by human decision-maker using his/her ability of comparing various aspects of the problem.
- The decision maker systematically compares the criteria in pairs and quantifies the relative importance either by available data or by intuitive judgment.
- The relative preferences found in pairs are then used to compute weights (priorities) for every part of the hierarchy model.
- The evaluation computed for all decision alternatives then shows their relative strength from the point of view of the entire problem.

- It is the advantage of AHP that even considerably diverse criteria can be used in the model, and that not only exact data but also human judgments can be applied to describe various aspects of the problem

Since 1977, Saaty proposed AHP as a decision aid to solve unstructured problems in economics, social and management sciences. AHP has been applied in a variety of contexts: from the simple everyday problem of selecting a school to the complex problems of designing alternative future outcomes of a developing country, evaluating political candidacy, allocating energy resources, and so on. The AHP enables the decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple criteria environment in the conflation [4].

The application of the AHP to the complex problem usually involves four major steps

1) Break down the complex problem into a number of small constituent elements and then structure the elements in a hierarchical form.
2) Make a series of pairwise comparisons between the elements according to a ratio scale.
3) Use the eigenvalue method to estimate the relative weights of the elements.
4) Aggregate the relative weights and synthesise them for the final measurement of given decision alternatives [4].

The AHP is a powerful and flexible multi-criteria decision-making tool for dealing with complex problems where both qualitative and quantitative aspects need to be considered. The AHP helps analysts to organise the critical aspects of a problem into a hierarchy rather like a family tree.

The essence of the process is decomposition of a complex problem into a hierarchy with a goal at the top of the hierarchy, criteria and sub-criteria at levels and sub-levels of the hierarchy, and decision alternatives at the bottom of the hierarchy. Figure 2.2 illustrates the scheme of the Analytic Hierarchy Process (AHP).

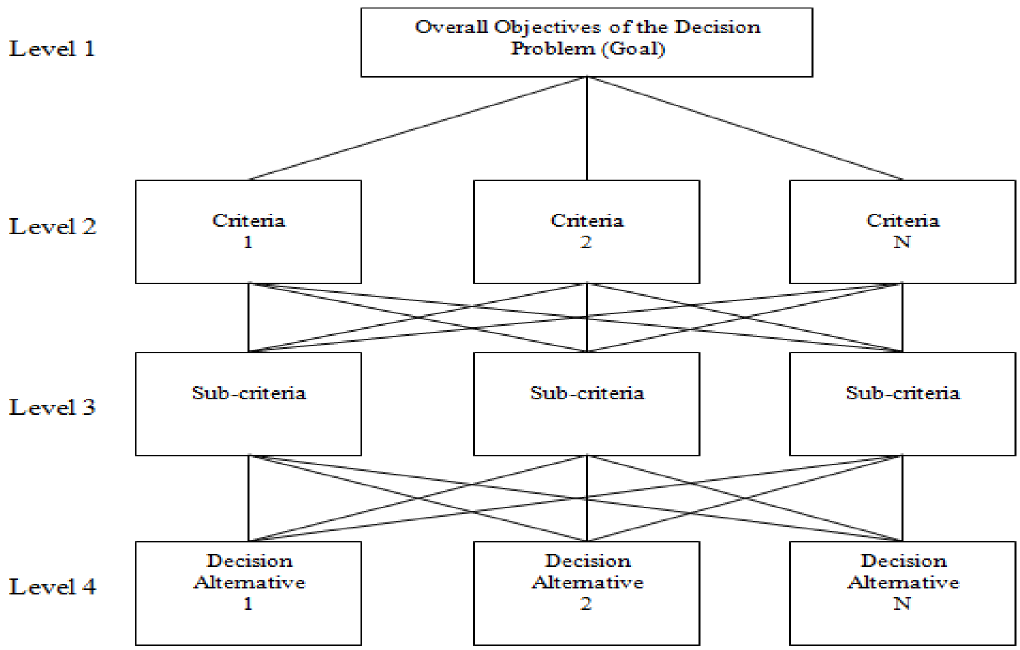

Figure 2.2: The Analytic Hierarchy Process (AHP) scheme [8].

Elements at the given hierarchy levels are compared in pairs to assess their relative preference with respect to each of the elements at the next higher level. The method computes and aggregates their eigenvectors until the composite final vector of weight coefficients for alternatives are obtained. The entries of the final weight coefficient vector reflect the relative importance (value) of each alternative with respect to the goal stated at the top of the hierarchy.

A decision maker may use this vector according to his particular needs and interests. To elicit pairwise comparisons performed at a given level, a matrix A is created in turn by putting the result of pairwise comparisons of element i with element j into the position a_{ji} as given in Equation (2.1) [8].

$$A = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ . \\ C_n \end{array} \begin{array}{c} \begin{array}{cccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & . & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & . & a_{1n} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} & . & a_{2n} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & . & a_{3n} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & . & a_{4n} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & . & a_{5n} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & . & a_{6n} \\ . & . & . & . & . & . & 1 & . \\ a_{n1} & a_{n2} & a_{n3} & a_{n4} & a_{n5} & a_{n6} & . & 1 \end{bmatrix} \end{array} . \quad (2.1)$$

Where

n = criteria number to be evaluated

C_i = i^{th} criteria, *(i=1,2,3,….,n)*

A_{ij} = importance of i^{th} criteria according to j^{th} criteria *(j=1, 2, 3… n)*

After obtaining the weight vector, it is then multiplied by the weight coefficient of the element at a higher level (that was used as the criterion for pairwise comparisons). The procedure is repeated upward for each level, until the top of the hierarchy is reached.

The overall weight coefficient, with respect to the goal for each decision alternative is then obtained. The alternative with the highest weight coefficient value should be taken as the best alternative. The Analytical Hierarchy Process is a well known decision-making analytical tool used for modeling unstructured problems in various areas, e.g., social, economic, and management sciences.

Table 2.3 shows the fundamental scale of values to represent the intensities of judgments. There are several intensities of importance. Each of the intensity of the importance is attached with the definition and explanation. Table 2.3 can be used as the reference when proceed to do the AHP analysis.

Intensity of importance	Definition	Explanation
1 2 3 4 5	Equal importance Weak Moderate importance Moderate plus Strong importance	Two activities contribute equally to the objective Experience and judgment slightly favour one activity over another Experience and judgment strongly favour one

6	Strong plus	activity over another
7	Very strong	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 nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with i	A reasonable assumption

Table 2.3: The fundamental scale of absolute numbers [8]

2.5 Fuzzy AHP

There is an extensive literature that addresses the situation where the comparison ratios are imprecise judgments. In most of the real-world problems, some of the decision data can be precisely assessed while others cannot. Humans are unsuccessful in making quantitative predictions, whereas they are comparatively efficient in qualitative forecasting.

Essentially, the uncertainty in the preference judgments gives rise to uncertainty in the ranking of alternatives as well as difficulty in determining consistency of preferences. These applications are performed with many different perspectives and proposed methods for fuzzy AHP. In this study, Chang's extent analysis on fuzzy AHP is formulated for a selection problem.

The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Despite the convenience of AHP in handling both quantitative and qualitative criteria of multi-criteria decision making problems based on decision maker's judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches.

Many researchers who have studied the fuzzy AHP which is the extension of the Saaty's theory, have provided evidence that fuzzy AHP shows relatively more sufficient description of these kind of decision making processes compared to the traditional AHP methods [4].

Pan [19] applied the fuzzy AHP approach for selecting the suitable bridge construction method. Lo & Wen proposed a fuzzy-AHP-based technique for the decision of design feature selection in Massively Multiplayer Online Role-Playing Game (MMORPG) development. Li & Huang applied fuzzy AHP to develop innovative designs for automated manufacturing systems. Dagderiren & Yuksel developed fuzzy AHP model behaviour-based safety management. Chamodrakas *et al*. integrated fuzzy AHP for selecting electronic marketplaces' supplier. Gumus applied fuzzy AHP for evaluation of hazardous waste transportation firms. Cakir & Canbolat designed a decision support system assisting a sensible multi-criteria inventory classification.

In complex systems, the experiences and judgments of humans are represented by linguistic and vague patterns. Therefore, a much better representation of this linguistics can be developed as quantitative data. This type of data set is then refined by the evaluation methods of fuzzy set theory. On the other hand, the AHP method is mainly used in nearly crisp (non-fuzzy) decision applications and creates and deals with a very unbalanced scale of judgment [4].

Therefore, the AHP method does not take into account the uncertainty associated with the mapping. The AHP's subjective judgment, selection and preference of decision-makers have great influence on the success of the method. The conventional AHP still cannot reflect the human thinking style. Avoiding these risks on performance, the fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems.

Chang's extent analysis on fuzzy AHP depends on the degree of possibilities of each criterion. According to the responses on the question form, the corresponding triangular fuzzy values of the linguistic variables are placed and for a particular level of the hierarchy the pairwise comparison matrix is constructed.

Subtotals are calculated for each row of the matrix and new *(l, m, u)* set is obtained, then in order to find the overall triangular fuzzy values for each criterion, $Li/\Sigma l_i$, $my/\Sigma m_i$, $ui/\Sigma u_i$, $(i=1, 2,..., n)$ values are found and used as the latest M_i (l_i, m_i, u_i) set for criterion M_i in the rest of the process. In the next step, membership functions are constructed for the each criterion and intersections are determined by comparing each couple [4].

In fuzzy logic approach, for each comparison the intersection point is found, and then the membership values of the points correspond to the weight of that point. This membership value can also be defined as the degree of possibility of the value. For a particular criterion, the minimum degree of possibility of the situations, where the value is greater than the others, is also the weight of this criterion before normalisation. After obtaining the weights for each criterion, they are normalised and called the final importance degrees or weights for the hierarchy level [4].

2.5 TOPSIS

TOPSIS is known as the "Technique for Order Preference by Similarity to Ideal Solution". This method is a unique technique to identify the ranking of all alternatives considered. In the TOPSIS method, the decision making matrix and weight vector are determined as crisp values and a positive ideal solution (PIS) and a negative ideal solution (NIS) are obtained from the decision matrix [11].

In other words, PIS is a set of best value of criteria while NIS is a set of worst values achievable of criteria. This method is applied to make wide-ranging evaluation of samples where it measured the distances between the index value vector of each sample and ideal solution along with the negative ideal solution of the comprehensive evaluation [12].

Hwang and Yon [13] are the first who introduces the TOPSIS method. Hwang and Yon describe multiple decisions making as follows: multiple decisions making is applied to preferable decision (such as assessment making priorities and choices) between available classified alternatives over the multiple attributes or criteria. It assumes that each criterion requires be maximising or minimising. Therefore, the ideal positive and negative values of each criterion are identified, and each alternative judge against this information.

It is noted that, in this typical multiple criterion decision making (MCDM) approaches, weights of attributes reflect the relative importance in the decision making process. Each evaluation of criteria entails diverse opinions and meanings. Hence, the assumption that each evaluation criterion is equally important is prohibited [14].

TOPSIS method consists of two artificial alternatives hypothesis which are 'Ideal Alternative' and 'Negative Ideal Alternative'. 'Ideal Alternative' represents the best level of all attributes considered while the 'Negative Ideal Alternative' represented the worst attributes value. With these two hypotheses, sets of calculations using eigenvector, square rooting and summations to obtain a relative closeness value of the criteria tested. These values of relative closeness, TOPSIS ranked the whole system by selecting the highest value of the relative closeness as the best attributes in the system.

Krohling & Campanharo did a case study of accidents with oil spill in the sea by using TOPSIS approach. Wang *et al.* applied TOPSIS to supplier selection. Sun & Lin used TOPSIS for evaluating the competitive advantages of shopping websites. Wang & Chang developed an approach in evaluating initial training aircraft under a fuzzy environment for the Taiwan Air Force Academy. Chamodrakas & Martakos applied TOPSIS method for energy efficient network selection in heterogeneous wireless networks.

METHOD	ADVANTAGES
AHP	• Better at computing index weight and comparing index in the same row than at ranking
FAHP	• Imprecise judgments of decision makers in conventional AHP approaches

TOPSIS	• A scalar value that accounts for both the best and worst alternative at the same time • A simple computation process that can be easily programmed into a spreadsheet

Table 2.4: Comparison of AHP, FAHP, and TOPSIS

2.6 Summary

This chapter has discussed about the literature reviews for this project. The purposes and conditions for the undergo load shedding process is discussed. Then, the classical AHP and fuzzy AHP are discussed. A few previous researches are mentioned for AHP and fuzzy AHP. Lastly, the TOPSIS is discussed.

CHAPTER 3

METHODOLOGY

3.1 Basic AHP procedure

Analytic Hierarchy Process (AHP) is a method developed for creating structured models of multi-criteria decision problems. The method helps to find an alternative which suits best the given needs of the deciding person. Analyzing the set of possible alternatives, the AHP method finds the one with the best rating, based on the structure of the problem and given preferences. Saaty formulated the principles of AHP in late 1970s (Saaty, 1980), and the method has been broadly studied and applied in many cases since the time.

AHP is a decision-making process in which a problem is first broken down into a hierarchy of interrelated decision elements and then uses the pairwise comparison that determined by the user to give the order in which factors affect a decision, consistency of the respondent, and a prioritized list of the decisions to be made. The process of AHP analysis can be shown in 3 steps.

3.1.1 Develop the weights for criteria

a) Develop a single pair-wise comparison matrix for the criteria. In this thesis, the ratio between criteria is obtained.

$$A_C = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \end{array}, i = 1,2,....n;\ j = 1,2,....n \qquad (3.1)$$

Where;

$C_1, C_2, ..., C_n$ are the criteria,

a_{ij} represents the rating of C_i with respect to C_j

b) Normalizing the n^{th} root of product to get the appropriate weights.

$$weight = \frac{n^{th}\ root\ of\ product}{\sum(n^{th}\ root\ of\ product)} \qquad (3.2)$$

c) Calculate the Consistency Ratio (CR) with the aid of the Random Index (RI) and CR must be less than 0.1 to make sure the result is reliable. If CR exceeds 0.1, the adjustments of the pair-wise values need to be done.

$$CR = \frac{CI}{RI} \qquad (3.3)$$

$$CI = \frac{Lambda\_Max - n}{n-1} \qquad (3.4)$$

$$Lambda\_Max = \sum(\sum column_{each\ alternative} \times weight_{per\ row}) \qquad (3.5)$$

Where:

$\Sigma column$ is the summation of pair-wise values of each alternative vertically. Random Index (*RI*) is a constant that standard for AHP analysis and is given as in Table 3.1.

Table 3.1: Random index

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

3.1.2 Develop the rating for each alternative in each criterion

The process is the same as in 3.1.1. However, the single pair-wise comparison matrix must be done for each criterion individually.

$$A_A = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \end{array}, i = 1,2,....n;\ j = 1,2,....n \qquad (3.6)$$

Where;

$A_1, A_2, \ldots, A_n$ are the alternatives,

a_{ij} represents the rating of A_i with respect to A_j

3.1.3 Calculate the overall weights and determine the priority

a) The final score for each alternative is the summation of the product of criteria to alternative.

b) There will be *n* number of overall weight and *n* must be an integer that does not exceed 9.

$$\begin{aligned} &Final\ \ score_{alternative\ X} = \\ &Criterion\ \ A \times Alternative\ \ X + Criterion\ \ B \\ &\times Alternative\ \ X + Criterion\ \ C \times Alternative\ \ X \\ &+ ... + Criterion\ \ I \times Alternative\ \ X \end{aligned} \tag{3.7}$$

Where;

Criterion A = 1st criterion, *Criterion B* = 2nd criterion, …, *Criterion I* = 9th criterion and $1 \leq X \leq 9$

c) The highest of the score shows the preceding load to be shed if compared with others. The process of the AHP analysis is illustrated in Figure 3.1.

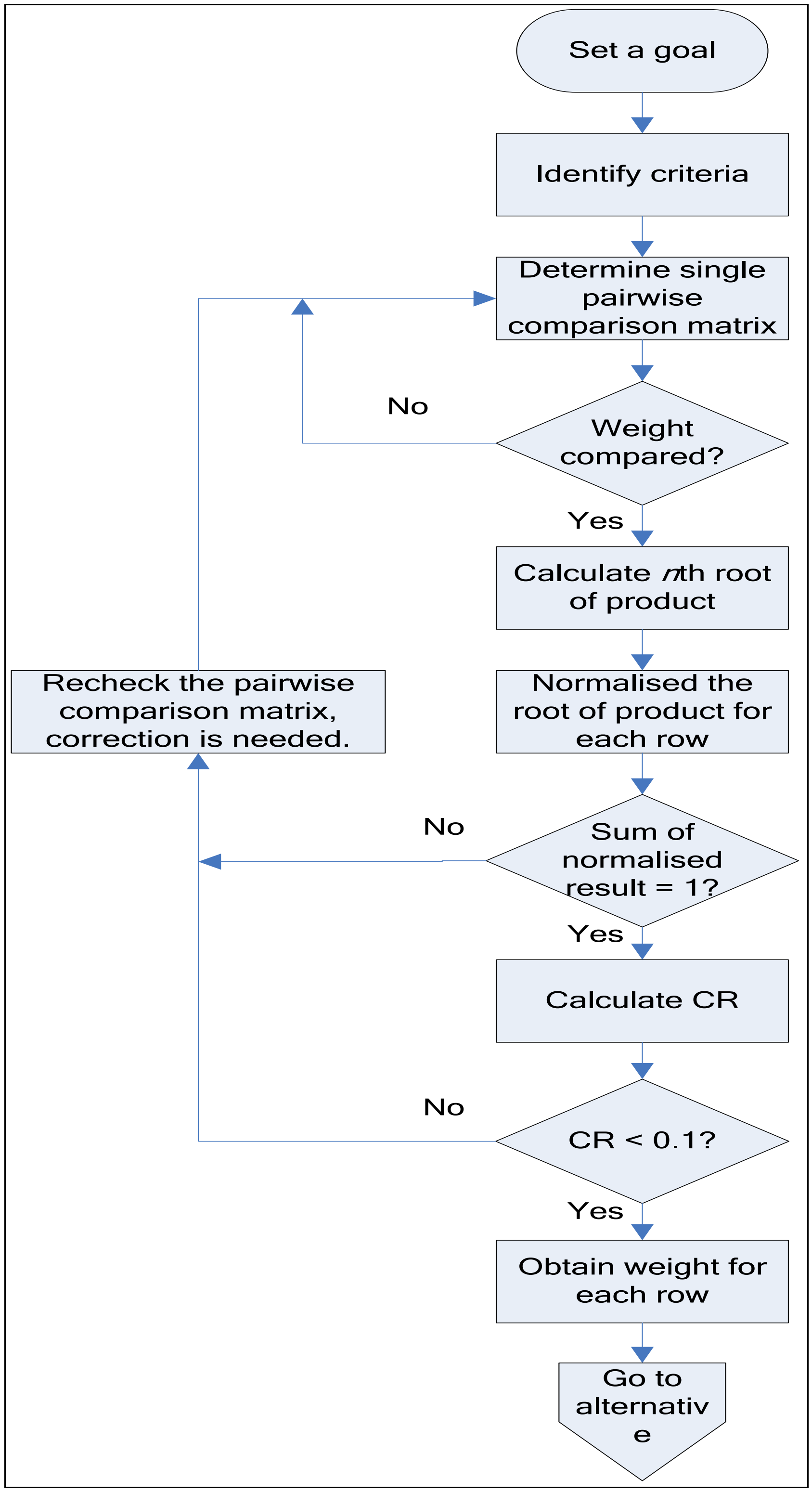

Figure 3.1: Flow chart of AHP analysis

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