Energy Planning using "Web-HIPRE" software

by

Alaa Eldin Adel Rabie Elgharib

Final Report submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL & ELECTRONICS ENGINEERING)

MAY 2011

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

Ir. Perumal Nallagownden

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ALAA ELDIN ADEL RABIE ELGHARIB

ABSTRACT

This Report is focusing on understanding Multi Criteria Decision Making. Most decision making requires the consideration of several conflicting objects the term multiple criteria decision making (MCDM) describes various methods for aiding decisions makers in reaching better decisions. The techniques provide solutions to the problem involving conflicting and multiple objectives. The aim of MCDM method is to help decision makers to organize and synthesize the information they have collected so that they feel comfortable and confident in their decisions. This project is to select the best and most suitable Energy planning/Power Plants using the Multi-Criteria Decision Making (MCDM) methods to come out with the best alternative. For every problem all the related factors regarding the discussed issue should be considered during the selection process. The aid of specialized software is being used to facilitate the decision making and to simulate the MCDM methods.

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CHAPTER 1
INTRODUCTION

1.1 Background of study

Decision-making problem is the process of finding the best option from all of the feasible alternatives. In almost all such problems the multiplicity of criteria for judging the alternatives is pervasive. That is, for many such problems, the decision maker wants to solve a multiple criteria decision making (MCDM) problem. Multiple criteria decision making may be considered as a complex and dynamic process in engineering level and any other level as well. The objective is to define the goals, and choose the final ''optimal'' alternative. The multi-criteria nature of decisions is emphasized, at which public officials called ''decision makers'' have the power to accept or reject the solution proposed by the engineering level. These decision makers, who provide the preference structure, are ''off line'' from the optimization procedure done at the engineering level. [1]

1.2 Problem statement

The Power Demand in Peninsular Malaysia has been increasing dramatically due to high economic growth and the increase of foreign companies in Malaysia. The very high dependency on oil has raised the issue of how long can the oil fuel can supply the power plants in Malaysia. Lately Energy Planning is taking an approach to the problem of planning for future energy needs based on structured decision making process. The selection of Power Plants kinds or sources will be questioned and other solutions for sustainable energy sources will be raised and suggested.

1.3 Objective

- Understand and get familiar with the Multi Criteria Decision Making
- Learn the different techniques and methods of the MCDM
- Apply MCDM on a small case study to prove its accuracy
- Work on a bigger scale by applying the MCDM methods on the Power Plants selection
- Getting familiar with the specialized software Web-HIPRE
- Using the MCDM to determine the best power plant alternative

1.4 Scope of study

MCDM can be applied in the technical, socio-economic, ecological and ethical prospective. So the working project has wide range of the scope. As mentioned above the project is to select the best way to find out and determine the best alternative in the selection of power plants, where it will be a great relief to the user/government distributing enough efficient power. MCDM can be used in any field of our life, we can use it to solve social, economical, and ethical issues [2].

CHAPTER 2

LITERATURE REVIEW

2.1 Multi Criteria Decision Making (MCDM)

Decision analysis looks at the paradigm in which an individual decision maker (or decision group) contemplates a choice of action in an uncertain environment. The theory of decision analysis is designed to help the individual make a choice among a set of pre-specified alternatives. The decision making process relies on information about the alternatives. The quality of information in any decision situation can run the whole gamut from scientifically-derived hard data to subjective interpretations, from certainty about decision outcomes (deterministic information) to uncertain outcomes represented by probabilities and fuzzy numbers. This diversity in type and quality of information about a decision problem calls for methods and techniques that can assist in information processing. Ultimately, these methods and techniques may lead to better decisions [3].

Our values, beliefs and perceptions are the force behind almost any decision-making activity. They are responsible for the perceived discrepancy between the present and a desirable state. Values are articulated in a goal, which is often the first step in a formal (supported by decision-making techniques) decision process. This goal may be put forth by an individual (decision- maker) or by a group of people (for example, a family). The actual decision boils down to selecting "a good choice" from a number of available choices. Each choice represents a decision alternative. In the multi-criteria decision-making (MCDM) context, the selection is facilitated by evaluating each choice on the set of criteria. The criteria must be measurable - even if the measurement is performed only at the nominal scale (yes/no; present/absent) and their outcomes must be measured for every decision alternative. Criterion outcomes provide the basis for comparison of choices and consequently facilitate the selection of one, satisfactory choice.

Criterion outcomes of decision alternatives can be collected in a table (called decision matrix or decision table) comprised of a set of columns and rows. The table rows represent decision alternatives, with table columns representing criteria. A value found at the intersection of row and column in the table represents a criterion outcome - a measured or predicted performance of a decision alternative on a criterion. The decision matrix is a central structure of the MCDM since it contains the data for comparison of decision alternatives [3].

2.2 MCDM Methods

Hundreds of MCDA methods have been proposed and applied over the years. The main idea in all of them was to be able to compare alternatives that have different performances levels for various criteria and to create a more formalized and better informed decision making process. However, non o these methods can be considered applicable in all decision making situations. There are too many different decision situations and not always the decision makers can be able to have the necessary amount of information required to use the perfect method for this situation [4].

In this report a Research on the most recent articles and papers regarding the MCDM in the last few years have been done to help the process of learning and understanding every method that have been used. This will also help the user to get a clearer picture and wider image on what is exactly is the MCDM and how it is applied in the real life.

From the research and studies done its obvious in most of the researches there is 3 very common methods are being used.

2.2.1 AHP method

AHP method is probably the best-known and most widely used model in decision making. AHP is a powerful decision making methodology in order to determine the priorities among different criteria. AHP is to decompose the decision problem into a hierarchy with a goal at the top, criteria and sub-criteria at levels and sub-levels of and decision alternatives at the bottom of the hierarchy [5].

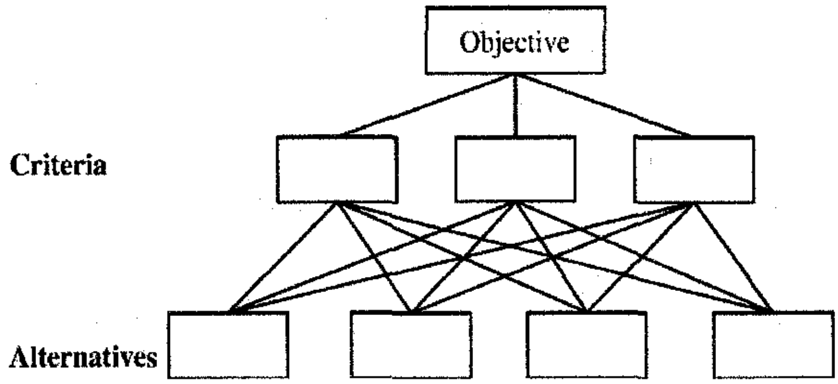


Figure 1: the hierarchical structure of decision making

2.2.2 TOPSIS Method

Multi-Criteria Decision Making (MCDM) is a collection of methodologies to compare, select, or rank multiple alternatives that involve incommensurate attributes. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is a multiple criteria method to identify solution from finite set of points.

TOPSIS Method is based on choosing the best alternative having the shortest distance to the ideal solution and the farthest distance from the negative-ideal solution [1].

2.2.3 Fuzzy Logic Method

Fuzzy decision support system in multi-criteria analysis approach for selecting the best plan alternatives or strategies it also determines the preference weightings of criteria for decision makers by subjective perception. It's very effective and it uses normal and simple words [1].

2.3 MCDM Steps

Steps of MCDM can be stated as establishing system evaluation criteria that relate system capabilities to goals, developing alternative systems for attaining the goals, evaluating alternatives in terms of the selected criteria, applying a normative multicriteria analysis method and accepting one alternative as "optimal"

There are 8 steps used in MCDM

1. Establish the decision context
2. Identify the alternatives or options to be appraised
3. Identify objectives and criteria
4. Scoring
5. Weighting
6. Calculate overall value
7. Examine the results
8. Sensitivity analysis

2.4 Energy Planning

Energy planning has a number of different meanings. However, one common meaning of the term is the process of developing long-range policies to help guide the future of a local, national, regional or even the global energy system in terms of generating electricity [6].

A new trend in energy planning known as Sustainable Energy Planning takes a closer approach to the problem of planning for future energy needs in terms of determining different alternatives in the kinds of power plants and the sources that could be used in term of supplying the needed energy supplies in the future. It is based on a structured decision making process, and my project will focus in analyzing the different alternatives of the Power Plants using the MCDM methods and the Web-hipre software to apply my methods and to facilitate the decision making for the user [6].

2.5 Power Plants

Power Plant is an industrial facility for the generation of electric energy. At the center of nearly all power plants is a generator, a rotating machine that converts mechanical energy into electrical energy by creating relative motion between a magnetic field and a conductor. The energy source harnessed to turn the generator varies widely. It depends chiefly on which fuels are easily available and on the types of technology that the power company has access to [7].

The power plant operator has several duties in the electricity-generating facility. Operators are responsible for the safety of the work crews that frequently do repairs on the mechanical and electrical equipment. They maintain the equipment with periodic inspections and log temperatures, pressures and other important information at regular intervals. Operators are responsible for starting and stopping the generators depending on need. They are able to synchronize and adjust the voltage output of the added generation with the running electrical system without upsetting the system. They must know the electrical and mechanical systems in order to troubleshoot problems in the facility and add to the reliability of the facility. Operators must be able to respond to an emergency and know the procedures in place to deal with it [7].

2.6 Types of Power Plants

There are many different types of power plants available and It all depends on the source of it. Some are using fuels like oil, gas and coal and some power plants are depending on the natural resources like the sun (solar), wind and hydro.

2.6.1 Pulverized Coal fired power plants

Pulverized coal plants account for the great majority of existing and planned coal-fired generating capacity. In this system coal is ground to fine power and injected with air into a boiler where it ignites. Combustion heat is absorbed by water-carrying tubes embedded in the boiler walls and downstream of the boiler. The heat turns the water to steam, which is used to rotate a turbine and produce electricity. Since about 2000 most plans for new pulverized coal plants have been for "supercritical" designs that gain efficiency by operating at very high steam temperatures and pressures [8].

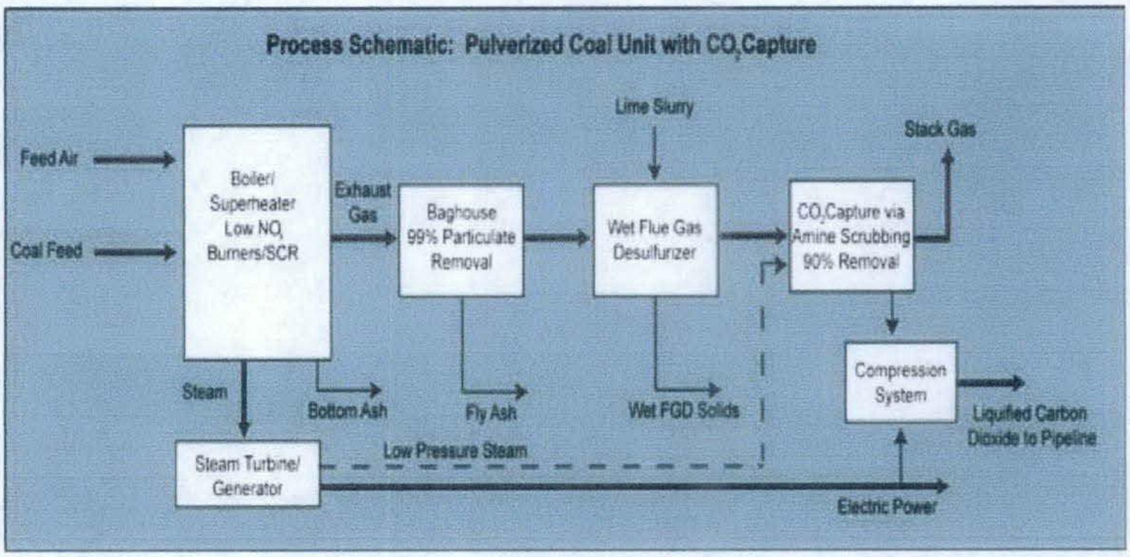


Figure 2: Process Schematic of Pulverized coal unit [8]

Figure 3: Coal Power Plant [8]

2.6.2 Natural Gas combined cycle Power Plants

Combined cycle plants are built around one or more combustion turbines, essentially the same technology used in jet engines. The combustion turbine is fired by natural gas to rotate a turbine and produce electricity. The hot exhaust gases from the combustion turbine are captured and used to produce steam, which drives another generator to produce more electricity. By converting the waste heat from the combustion turbine into useful electricity the combined cycle achieves very high efficiencies, with heat rates below 7,000 btus per kWh (compared to around 9,000 btus per kWh for new pulverized coal plants). This high efficiency partly compensates for the high cost of the natural gas used in these plants [8].

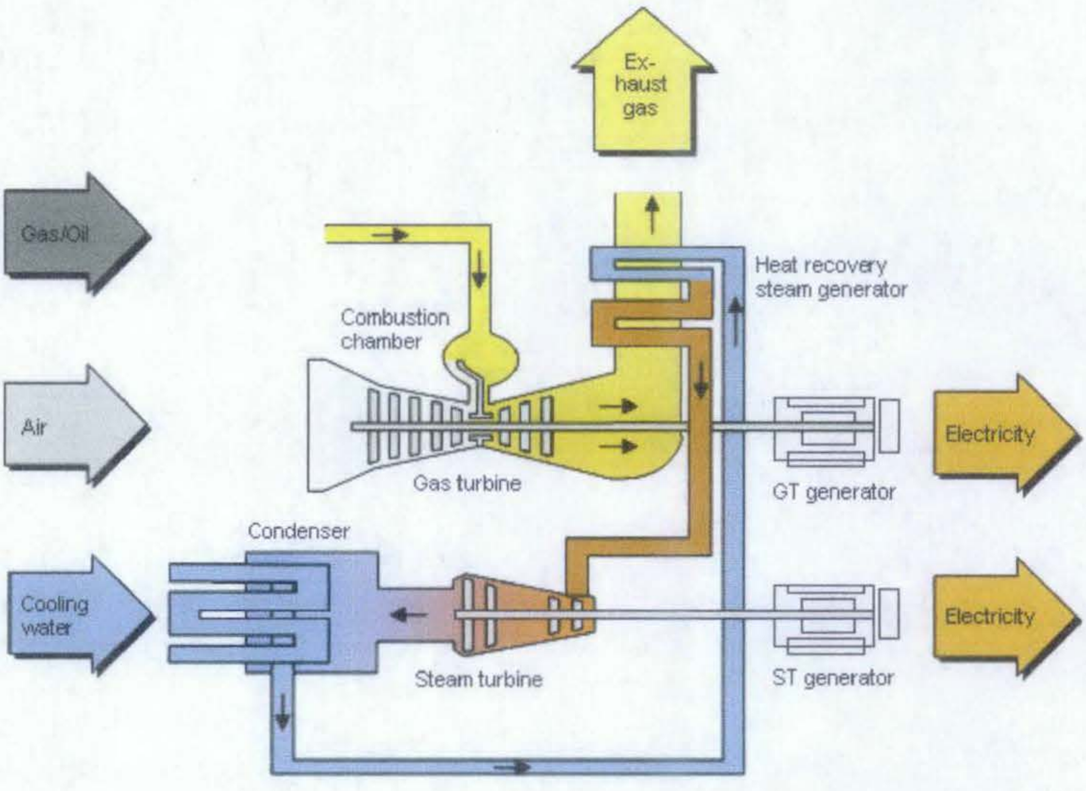


Figure 4: Natural Gas Schematic [8]

Figure 5: Natural gas power plant [9]

2.6.3 Nuclear Power Plant

Nuclear power plants use the heat produced by nuclear fission to produce steam. The steam drives a turbine to generate electricity. Nuclear plants are characterized by high investment costs but low variable operating costs, including low fuel expense. Because of the low variable costs and design factors, nuclear plants operate exclusively as base load plants and are typically the first plants in a power system's dispatch order [8].

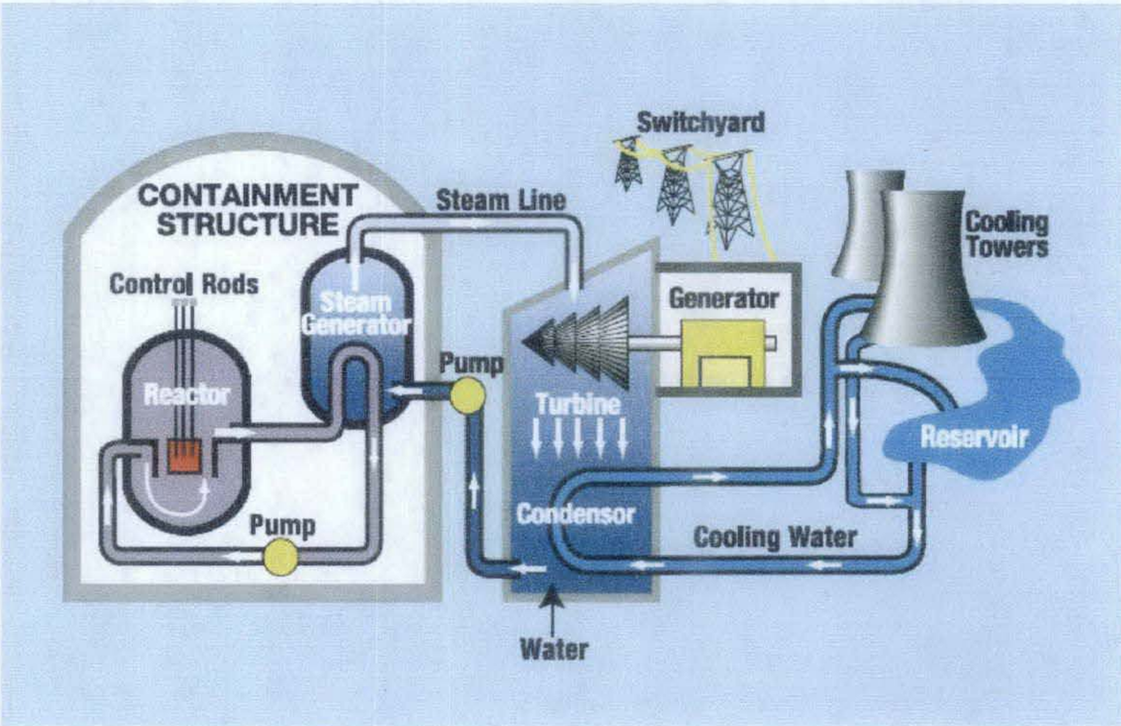


Figure 6: Process Schematic of Nuclear Power plant [8]

2.6.4 Wind Power Plant

Wind power plants (sometimes referred to as wind farms) use wind-driven turbines to generate electricity. An individual turbine typically has a capacity in the range of 1.5 to 2.5 MW, and a wind plant installs dozens or hundreds of these turbines. As noted above, wind is a variable renewable resource because its availability depends on the vagaries of the weather [8].

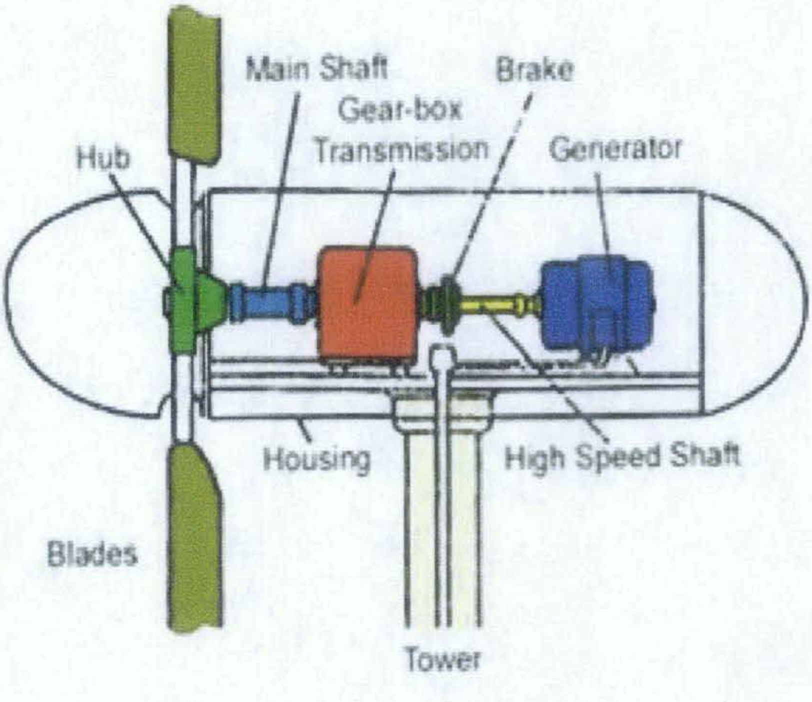


Figure 7: Wind tower Process Schematic [8]

Figure 8: Wind Farm [10]

2.6.5 Photovoltaic Solar Power Plant (Solar PV)

Solar thermal and PV power are alternative means of harnessing sunlight to produce electricity. PV power uses solar cells to directly convert sunlight to electricity [8].

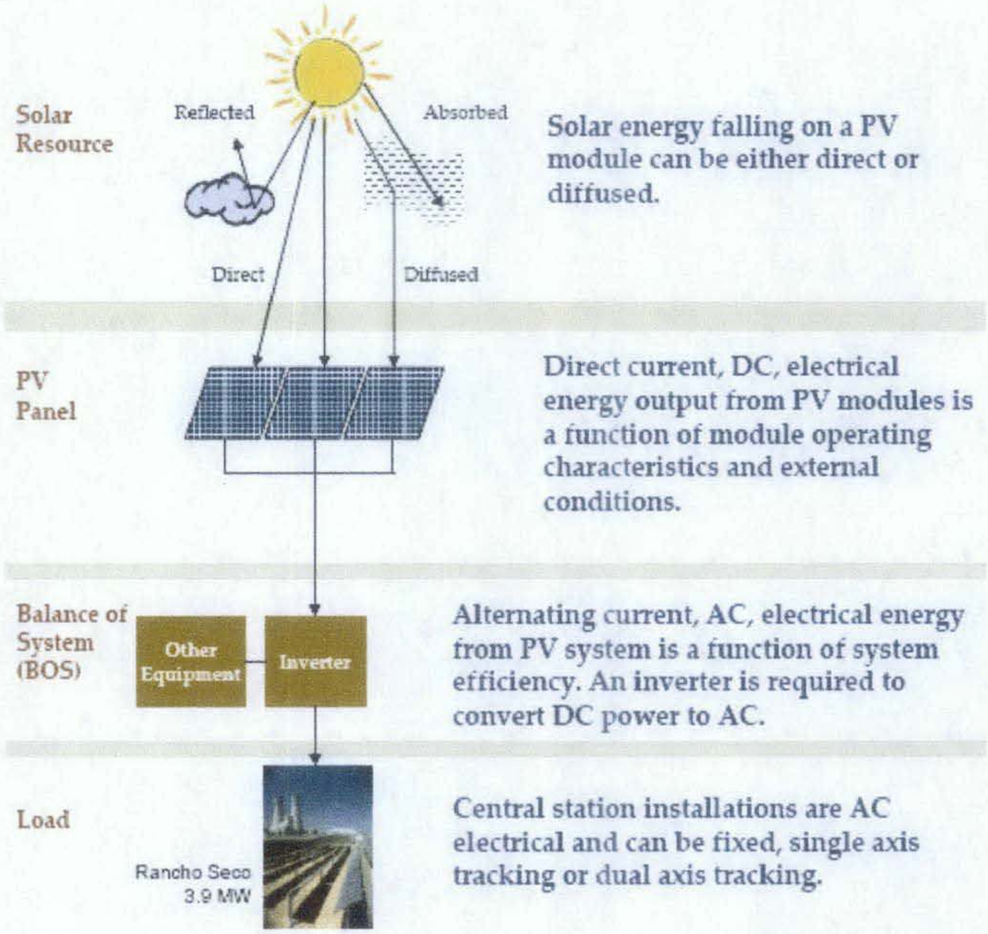


Figure 9: Process Schematic for PV Solar [8]

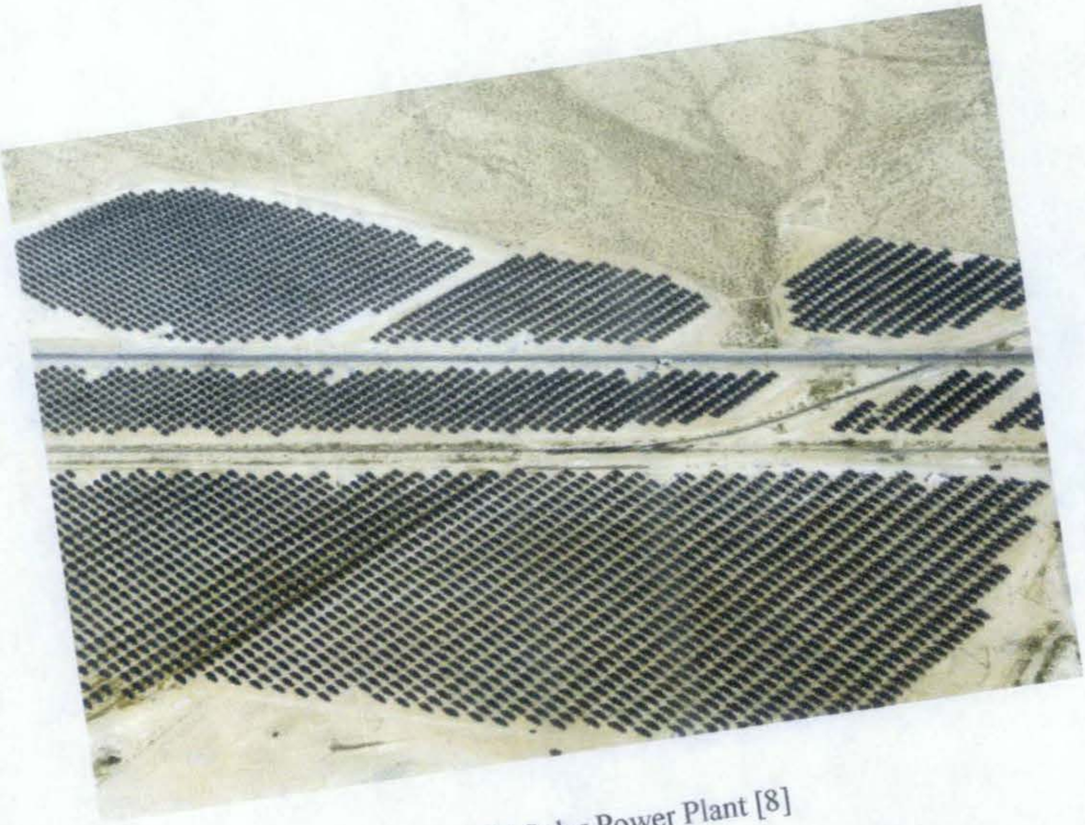


Figure 10: PV Solar Power Plant [8]

2.6.6 Solar thermal Power Plant

Solar thermal plants, also referred to as concentrated solar power (CSP), concentrate sunlight to heat a working liquid to produce steam that drives a power generating turbine [8].

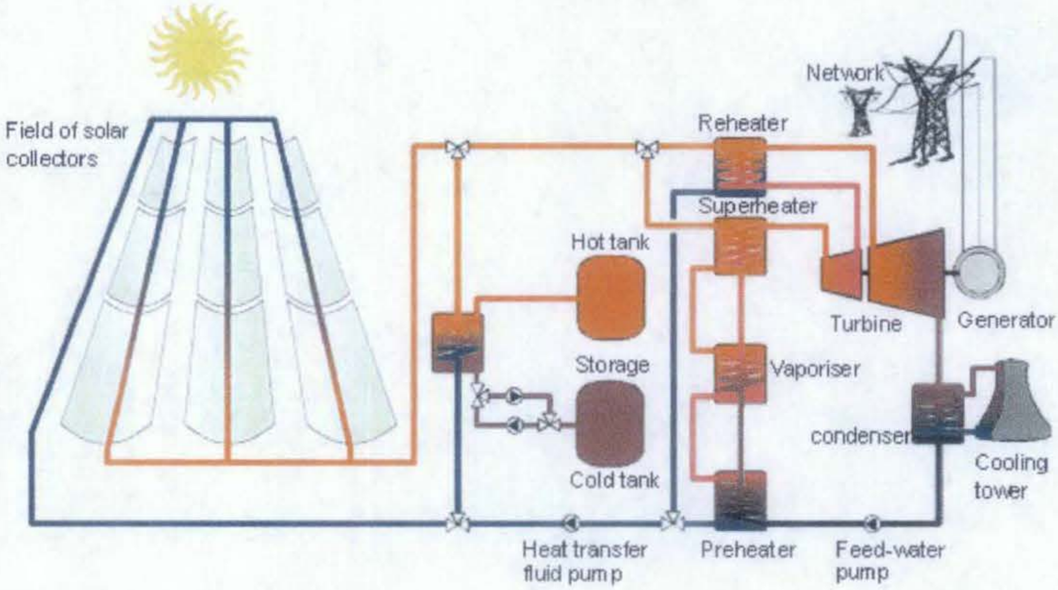


Figure 11: Thermal Process Schematic [8]

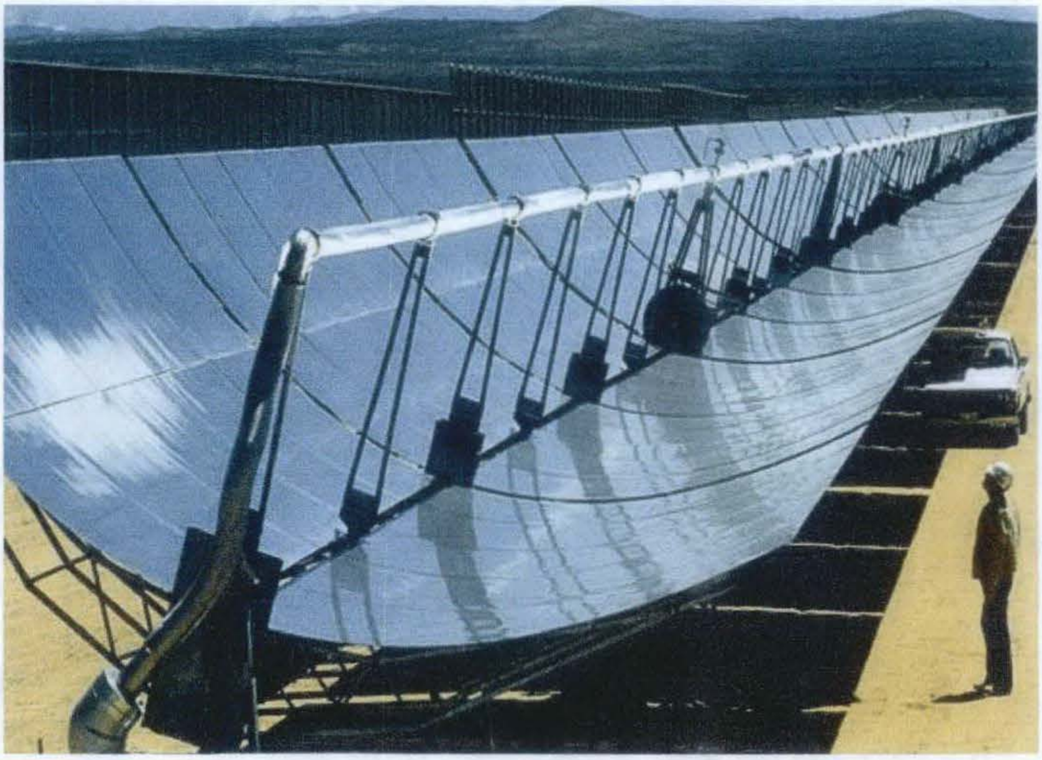


Figure 12: Thermal solar panels [11]

2.7 Port Dickson Power Plant

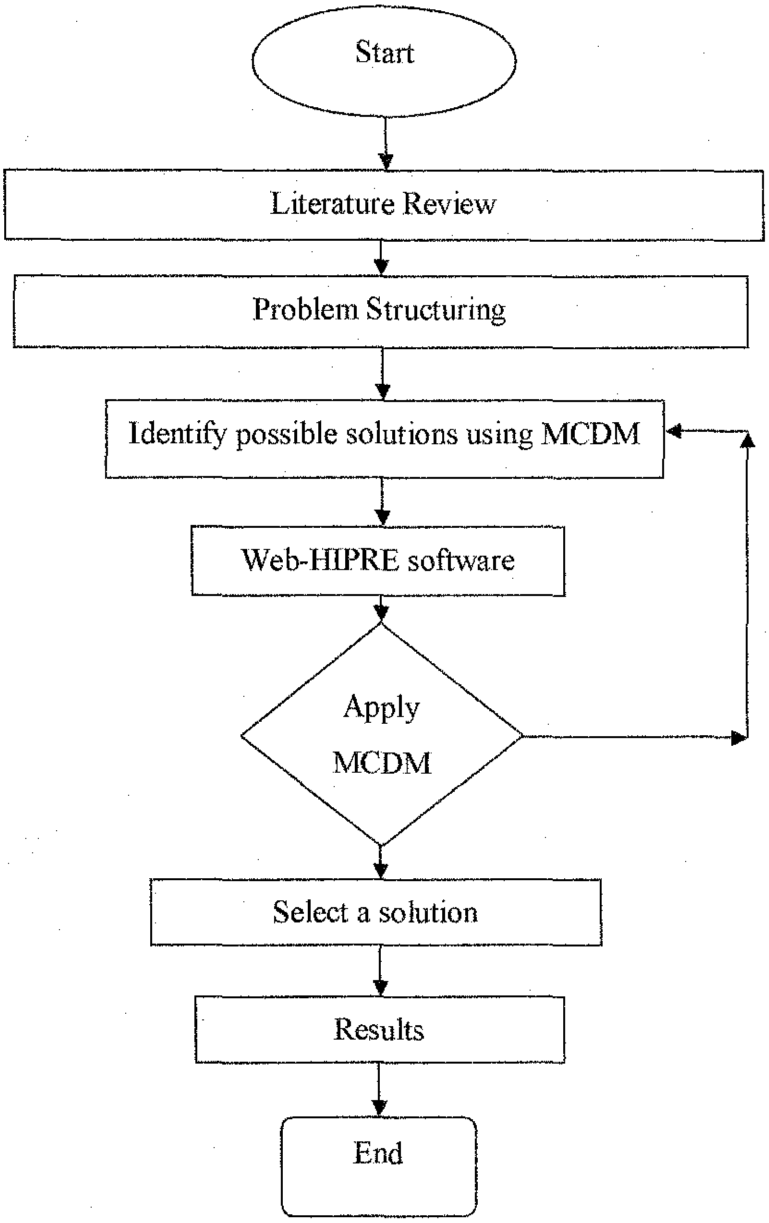
Port Dickson Power station is in Malaysia, located in Port Dickson, Negeri Sembilan. Construction began in 1975 and was completed in 1978. The main station was officially opened on 1979 by H.R.H Tuanku Jaafar of Negeri Sembilan. The Power Plant is owened by Tenaga Nasional Berhad (TNB) [12].

The Plant uses oil fired power plant which is deteriorated and inefficient since in Peninsular Malaysia the power demand has been dramatically increasing and since most of the power demand is concentrated on Kuala Lumpur area and Putra Jaya. The Malaysian government decided that the oil fired Power plants is no longer efficient and they raised a huge concerns on the availability of oil in the very near future so they have decided to replace the oil fired with highly efficient combined cycle gas turbine power generation with low emission of poisonous gas since Port Dickson is a city with schools, hospitals and even a tourist spot.

The Government had certain expectations from replacing oil fired into natural gas combined cycle in terms of efficiency, power supply, CO2 emission, power costs, maintenance costs, fuel costs and etc. This Project is not going to only look at how the government can use combined cycle gas It will also suggest several kinds of power generations to be compared according to the government's specification having in mind several points which are the fuel availability in the future which is a huge concern.

Figure 13: Port Dickson Power Plant [13]

CHAPTER 3
METHODOLOGY



3.1 Tools:

The software Web-HIPRE is used for the completion of this project. This software is used for the Multi-criteria Decision Analysis, The Project enables the user to try and explore the software to an extent that can make the user able to use it to some reasonable extant in applying the MCDM methods and getting the results desired for the project.

3.1.1 Web-HIPRE:

Web-HIPRE (HIerarchical PREference analysis on the World Wide Web) (Hämäläinen and Mustajoki, 1998) is a WWW software for multi-criteria decision analysis based on the well-known decision support software HIPRE 3+. It provides an implementation of multi-attribute value theory (MAVT) and the analytic hierarchy process (AHP) to support the different phases of decision analysis, i.e. structuring of the problem, prioritization and analyzing the results. We can access it from everywhere in the world because it is located on World Wide Web (WWW) [14].

There are few steps for decision making using Web-HIPRE:

Web-HIPRE is available on http://www.hipre.hut.fi/ , when we browse it, and then click the "Bring Web-HIPRE to Font" button, it will reveal a popup window and then further clicking the popup window it will reveal a new window where all the models will be created and all weights will be given for the decision making.

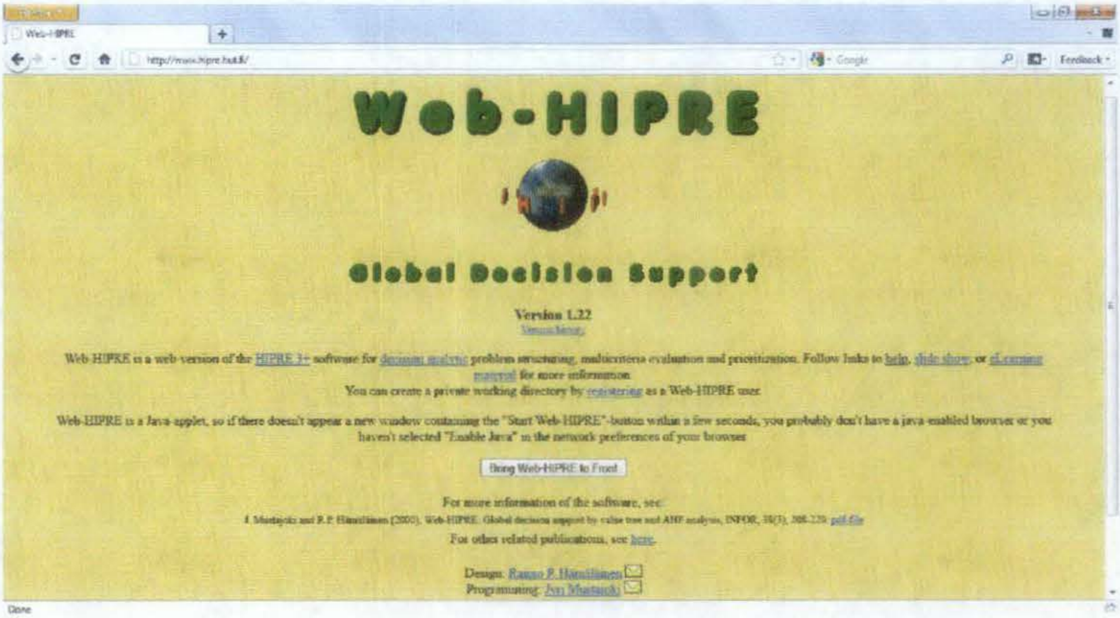


Figure 14: Web-HIPRE home page [16]

How to start a new a new model?

After clicking on the "Bring Web-HIPRE to front" button a new window will appear

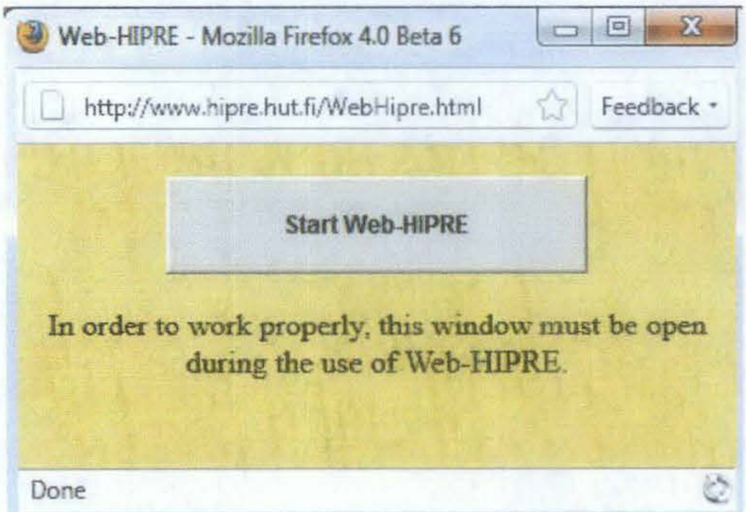


Figure 15: Start Web-HIPRE

If you click on "Start Web-HIPRE" another window will open up, and this window is the one which you will be able to create your model in.

Model:

HIPRE - HIerarchical PREference analysis software is used for multi-attribute (multi-criteria) decision analysis, where the decision problem is structured hierarchically from criteria to lower level subcriteria. The resulting model is called a value tree or a hierarchy of criteria and objectives depending on the tradition referred to. So HIPRE handles both multi-attribute value trees and Analytical Hierarchy Process (AHP) models as well as their combinations.

Elements of the value tree:

The lowest level (the rightmost) elements of the value tree are automatically handled as alternatives and they are colored yellow. The other elements represent the overall goal and objectives or criteria and attributes (colored cyan), depending on the tradition referred to. Different traditions use different names, but in practice there is no difference. When creating, connecting or moving the elements of the value tree, all kind of elements are handled in the same way without taking any notice on their functionality.

Creating a new element:

To create a new element into the value tree, double-click on the corresponding place in the decision model area.

Activating an element:

To activate an element, click the left mouse button on the element. To activate multiple elements hold down the SHIFT key and click on the each element you want to activate. Activated elements are of dark blue.

Changing the name of an element:

To change the name of an element, activate the element and press ENTER. Another way is to choose Edit element name in the Model -menu.

Connecting elements:

The hierarchical structure of the model is created by connecting the elements. To connect elements to a desired element, activate the elements you want to connect and click the right mouse button on the element to which you want the activated elements to be connected.

Disconnecting elements:

To disconnect elements from desired element, activate elements you want to disconnect and click right mouse button on the element from which you want the activated elements to be disconnected.

Moving elements:

To move an element, click left mouse button on element to be moved, drag element to the desired place while holding down the mouse button and drop element by releasing the mouse button.

Deleting elements:

To delete elements, activate all elements you want to delete and press DELETE.

Weighting sub-elements:

To open the weighting window, double-click on the corresponding element. Another way is to choose the weighting method in the Priorities-menu.

Rating alternatives:

To open the rating window, double-click on any alternative. Alternatives are colored yellow. Another way is to choose Ratings in the Priorities-menu.

Changing the name of heading:

To change the name of heading, activate heading and press ENTER. To let Web-HIPRE to handle the naming of headings, change the name of heading to automatic (which is default).

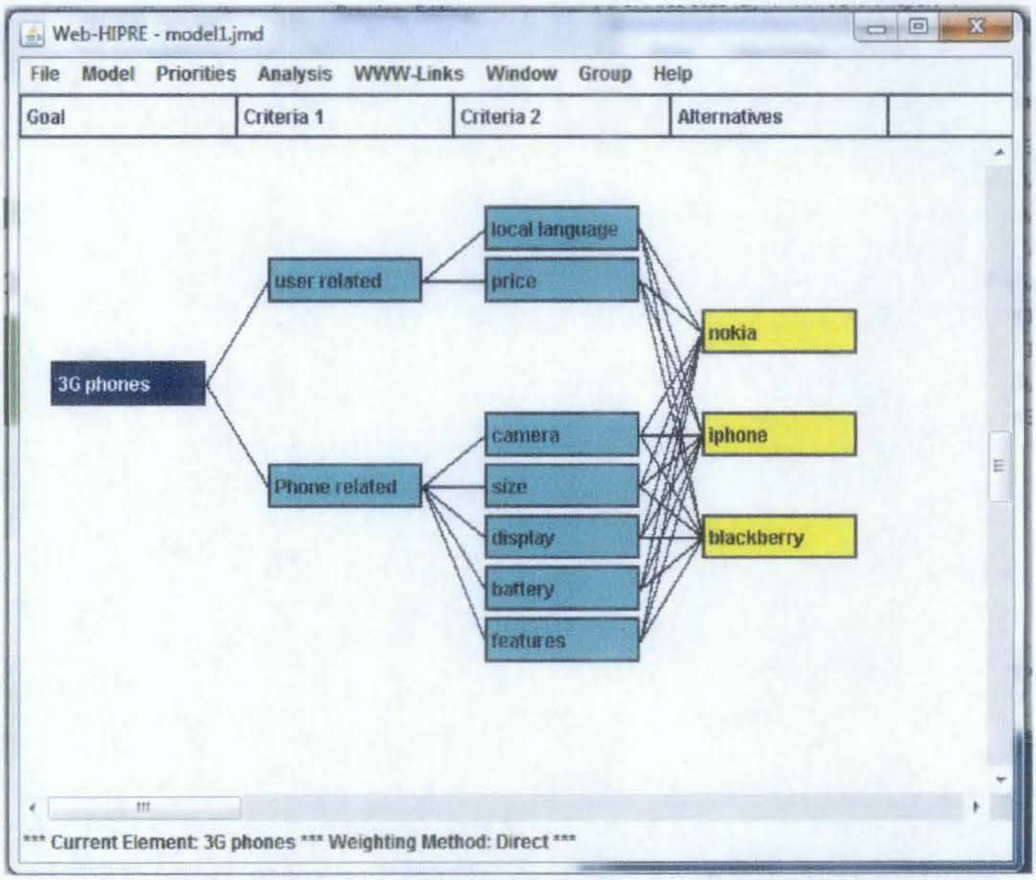


Figure 16: A model with Goal criteria's and alternative

In Figure 16 we can see how the Goal is colored in blue and the alternatives are colored in yellow, they are all connected. So in oreder for us to create a model like this one we have to choose New in File-menu, when Web-HIPRE creates a new blank decision model area. Open models can be switched in Window-menu.

Opening a model:

To open an existing model choose Open... in File-menu. In appearing Open File - dialog, you can open file by choosing corresponding filename from the filename list and pressing Open file -button. If you have registered as a Web-HIPRE user, you can open your private directory by defining your user name and password. There exists also some <read only> example models in the file list.

Saving a model:

To save current model choose Save in File-menu. In appearing Save File - dialog, you can save current model by defining file name in corresponding text field and pressing Save file -button. To save model into your private directory (only if you are a registered Web-HIPRE user), define your user name and password in corresponding text fields. To register as a Web-HIPRE user, press Register as a new user -button, when registeration web page opens in a new browser window.

Removing file from disk:

To remove file from disk, choose Remove from disk... in File-menu. In appearing Remove File -dialog, you can remove file from disk by choosing file to remove from file list and pressing Remove file -button. To change to your private directory, define your user name and password in corresponding text fields.

Opening Priorities –dialog:

To open Priorities -dialog, double-click on the corresponding element in value tree. Another way is to choose the weighting method directly in Priorities menu.

Direct weighting:

In direct weighting, the weights of sub-criteria or alternatives are directly given. You can give the weights by writing them into corresponding text fields or using the slider. To normalize the weights, press Normalize now -button, when the sum of weights is set to one. On the alternative level you can choose whether to normalize weights in analysis (when Normalize weights in analysis -tickbox is ticked) or alternatively use weights as values of alternatives (tickbox not ticked).

You can also bring in weights calculated in the pairwise comparisons (Import pairwise) or values from value function (Import valuefn).

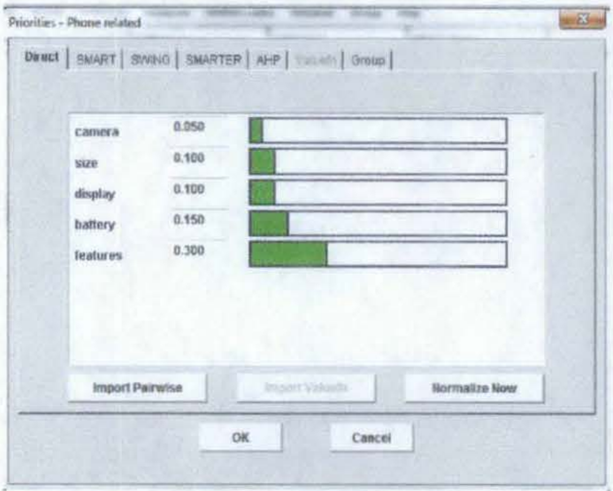


Figure 17: weighting the criteria's

One thing about the Web-HIPRE is that it has a huge advantage that it ables you to use more than one method at the same time. Another unique feature is that in each hierarchy you can use a different weithing method which is most suitable for the user. All the data will be stored which allows the user easy testing of the priotirization methods.

So in oreder to Analyse the results, open Analysis –dialog biz, choosing either Composite Priorities or Senstivity Analysis-menu. When **Choosing the Goal** the composite piorities are calculated and taken into respect. And in **Choosing segment** you choose the level of hierarchy which determines how the composit priorities bars are devided into the segments. These segments show the relative conributution of these elements to the global weights of bars. When u Choose bars, you choose the level of hierarchy, the elements of which are shown by the bars.

To show Values or click on *Show Value –tickbox*. Graphical form is obtained and if u want the results in text form u click *Results as Text*

Sensitivity Analysis: shows the sensitivity in the changes of the total weights in respect to the local weight of some criterion (or value of some alternative) varying. First you are asked to choose the criteria under which the weight of subcriteria is varying and the subcriteria (or alternative) whose weight is varying. The graph then shows how the total weights of alternatives change in subject to the local weight of the chosen subcriteria varying. The current total weights of alternatives can be read on the black vertical line which is in the position of the current local weight of the varying criteria. By clicking mouse button on graph you can add another vertical line showing which the total weights of alternatives would be if the local weight of chosen subcriteria is at this point.

AHP Pairwise Comparison scale: in the AHP Pairwise comparison criteria's are to be compared in the level or the intensity of importance of one criteria compared to the other. A scale from 1 to 9 is used where 1 is Equal Importance and 9 is Extreme Importance and after comparing all the criteria's with each other the weighting will be done according to the level of importance of each criteria.

3.2 Selection Criteria:

Comparing the selection criteria's of the power plants with the Port Dickson characteristics and features my MCDM methods will take place and my alternatives will be compared and weighted.

3.2.1 Operation Cost (set up)

For every power plant it has different operation cost in order to get the plant running and being able to supply the power needed, the comparison will be based on much money will it cost one power plant to produce 1 Mega Watt (MW) of Power.

3.2.2 Maintenance Costs

Maintenance is a very important criteria and for each power plant the Maintenance costs will be compared on how much will it cost each Power Plant to maintain 1 Mega Watt per Hour (MW-h)

3.2.3 Fuel Cost

Lately the price of the oil fuel has been increasing dramatically due to its high demand so in this criteria we will compare the power plants in how much does it cost its fuel consumption in Mega Watt per Hour (MW-h)

3.2.4 Fuel Availability

One huge advantage in the natural power sources like solar and wind is that it doesn't need fuel to run their power plants, it totally depends on natural resources. On the other hand other power plants needs expensive fuel to fire up their plants and the question raised is how long can that fuel support the power plant and when is it going to finish.

3.2.5 Efficiency

The higher the efficiency of the Power Plant the better and on that prospective the alternatives will be compared.

3.2.6 CO2

The CO2 gas is produced as an exhaust of the power plants and the lower the amount of CO2 the power plant produces the better, the alternatives will be compared on how much Kilo Grams CO2 gas is produces per Kilo Watt Hour (kg Co2/KWh)

3.2.7 Area

Port Dickson area is 0.27 km2 and on this number the alternatives will be compared in terms of the needed area for each power plant and weather its suitable to take a place in the Port Dickson Plant or not.

3.2.8 Electricity Cost

The higher the electricity cost the better and the alternatives will be compared on how much will it cost one power plant to produce 1 Kilo Watt per hour (KW-h)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

The Web-HIPRE software is used to compare the different kinds of Power Plants Alternatives a firstly a model was created. In the Figure below shows the main model or the main screen of the Web-HIPRE software model. The first column is to be the objective which is the power plant selection, the second column is the first criteria and the second column will include the subcriteria's. The last column will be my 6 alternatives which are coal, solar PV, Nuclear, Gas, Wind and Solar thermal.

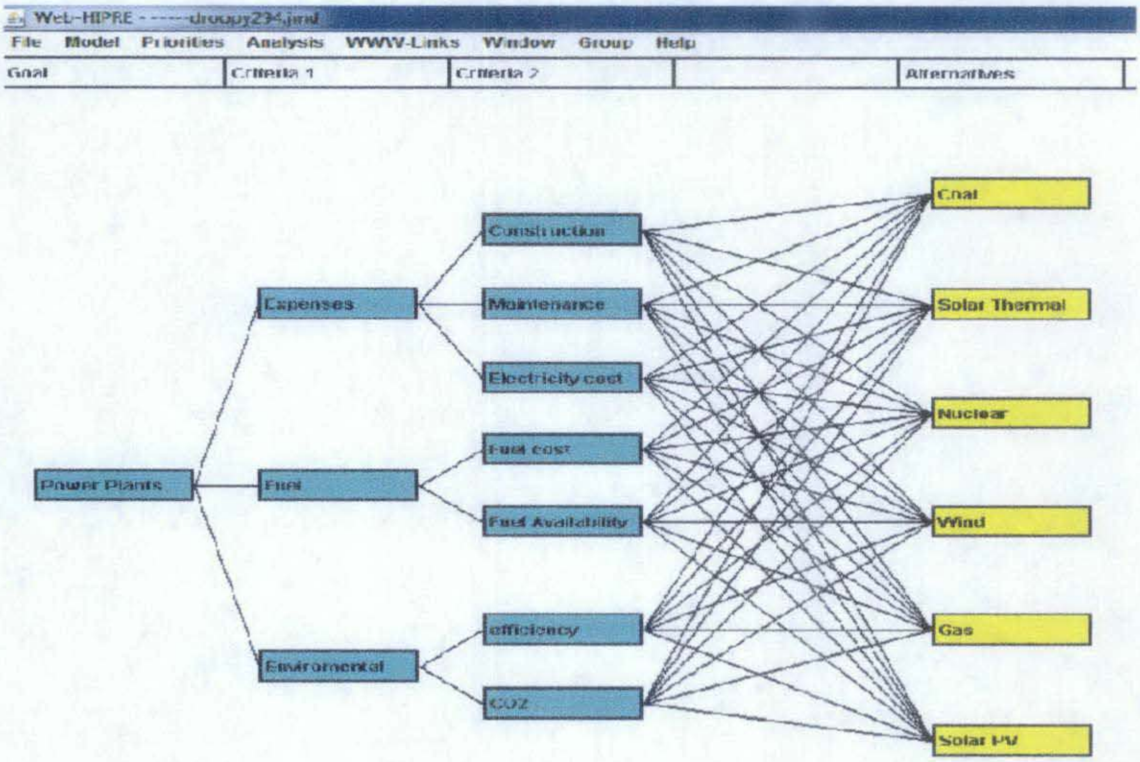


Figure 18: Web-HIPRE main model layout

The performance matrix was to be constructed where in this table all the actual data is written down and listed for consideration, all the information we can get it from the performance matrix, it gives information about the goal, criteria's and the alternatives to be considered. The alternatives are Coal, Solar PV, Nuclear, Wind, Solar Thermal & Gas. The values are shown below in Table 1.

Table 1: Performance matrix for Power Plants Selection [17]

Power Plants	Operation costs Usd/MW	Maintenance costs Usd/MW-h	Fuel Costs Usd/MW-h	Fuel Availability	Efficiency (%)	CO2 Kg/kw-h	Area Km2	Electricity cost Usd/KW-h
coal	1 mill	5	11.13	-	43	0.82	0.4	5.4
Solar Thermal	3.5 mill	1	0	✓	15	0.1	0.08	17
Nuclear	2.3 mill	6	5.29	-	33	0.025	0.01	4
Wind	1.1 mill	2	0	✓	28	0.02	0.79	7
Gas	0.65 mill	5	30.57	-	38	0.38	0.04	4
Solar PV	4.5 mill	1	0	✓	10	0.1	0.12	75

Now weights are given to the criteria's. Firstly for the first criteria which is the expenses, fuel and environmental, direct weighting has been used to compare the 3 of them as shown in Figure 18 below where it prioritized each one of them.

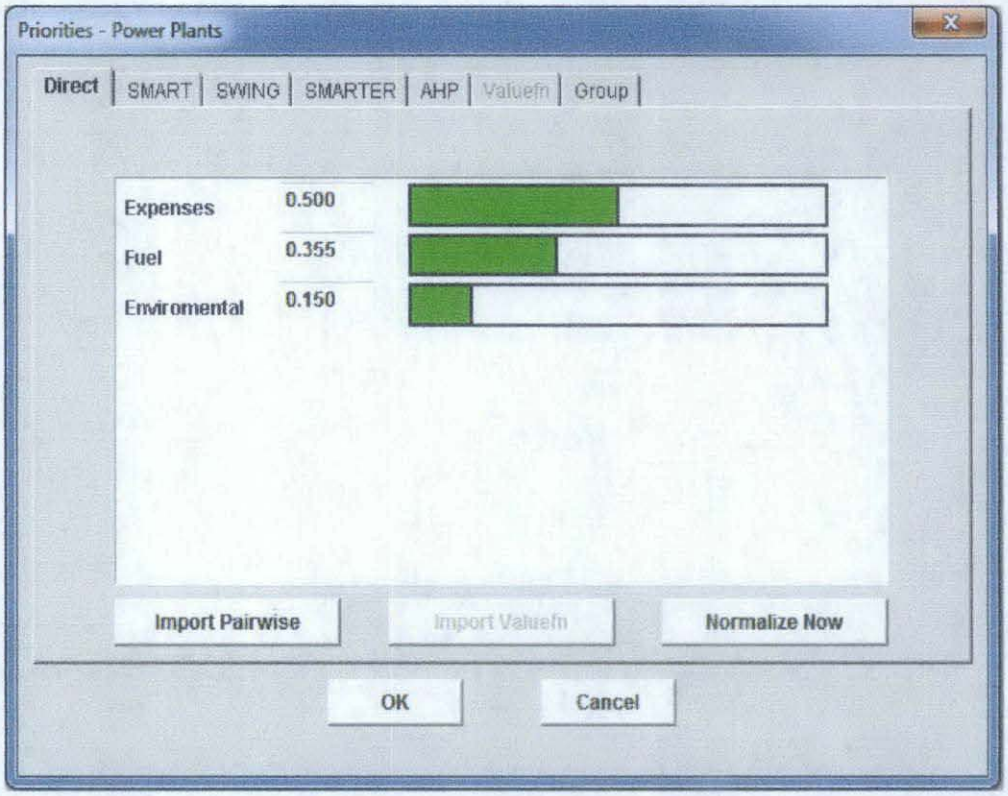


Figure 19: Weighting the first criteria

Now weights are given to the criteria using AHP pair-wise comparison method, this is to compare which criteria is more important than the other. So as shown in the 3 figures below Figure 19, Figure 20 and Figure 21 where a scale from 1 to 9 is given where 1 means equally preferred to the other criteria and 9 means extremely preferred than the other criteria. As shown in the figures below the subcriteria's have been compared using the AHP method. The subcriteria's for expenses, fuel and environmental are all compared. In the expenses in Figure 19 we can see that the most important criteria was the operation costs followed by the maintenance costs then the electricity costs.

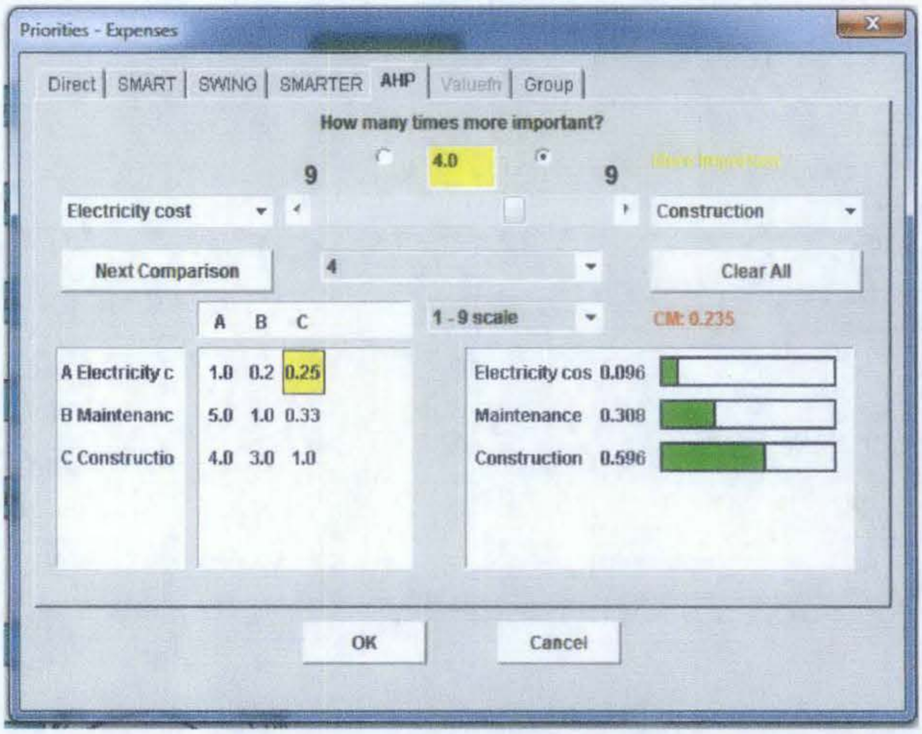


Figure 20: AHP comparison for the Expenses

And in the Fuel AHP comparison in Figure 20 we can see that the Fuel costs is more important than that fuel availability.

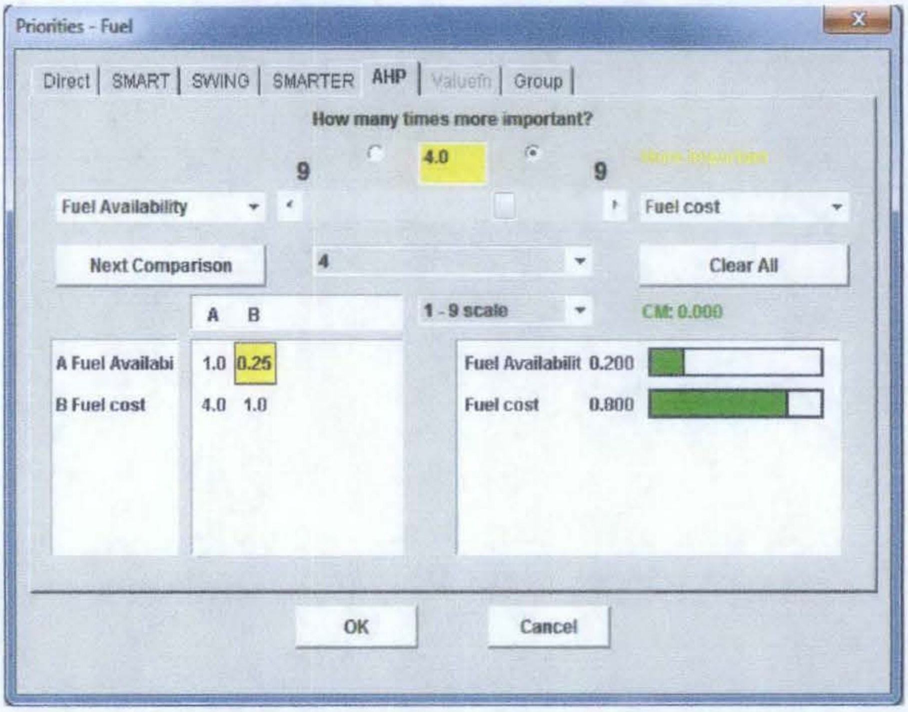


Figure 21: AHP comparison for the Fuel

And in the Environmental AHP comparison shown in Figure 21 we can see that the efficiency is more important than the CO2 emission The comparison and which criterion is more important than the other is shown in the 3 figures below. Then we get the overall weight for all criteria by adding each column with each row and then divide each element in the row by column's sum, this will give us overall weight of that particular criteria.

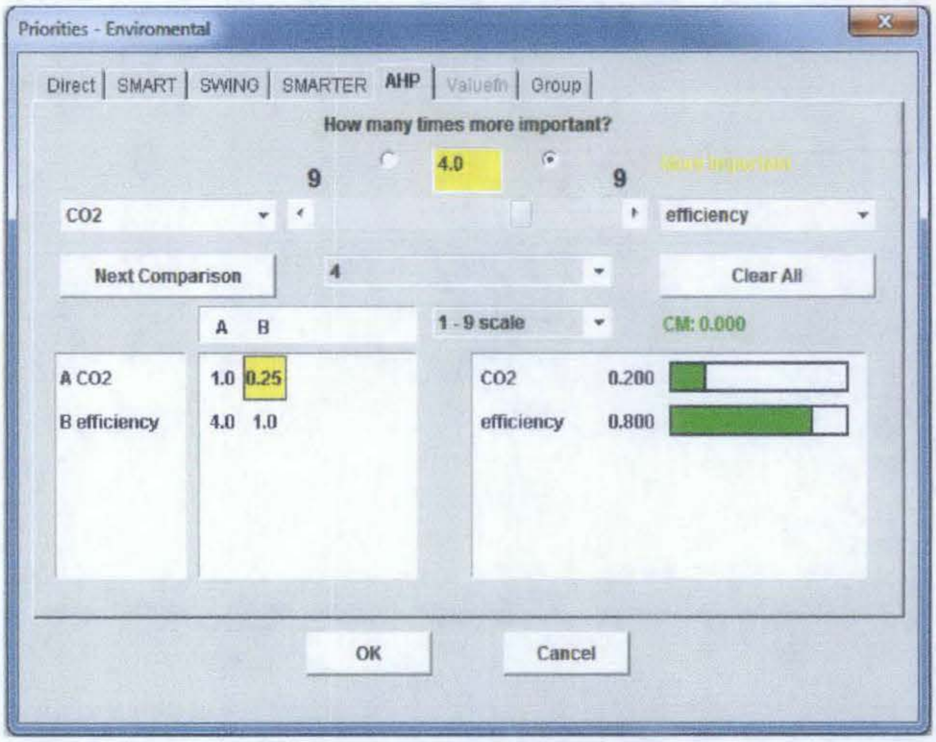


Figure 22: AHP comparison for Enviromental

After assigning the weights to all criteria, now using the performance matrix table for the different power plants, the values has been assigned to all the alternatives we have for the each criterion using the direct method in Web-HIPRE.

In this step it is shown that what is for example the construction costs of all power plants to do this the value is given from 0 to 1 according to the actual value of the cost of that particular power plant, 1 is given to the power plants which are has the lowest operation costs. All the values must be in the range from 0 to 1. Similarly the figure below shows the values of the operation, maintenance, electricity costs and the fuel costs, fuel availability and the efficiency and the CO2 emission. All are shown in the figures below.

In the Figure 22 the direct weighting is shown for the 3 alternatives: construction, maintenance and the electricity costs for each power plant.

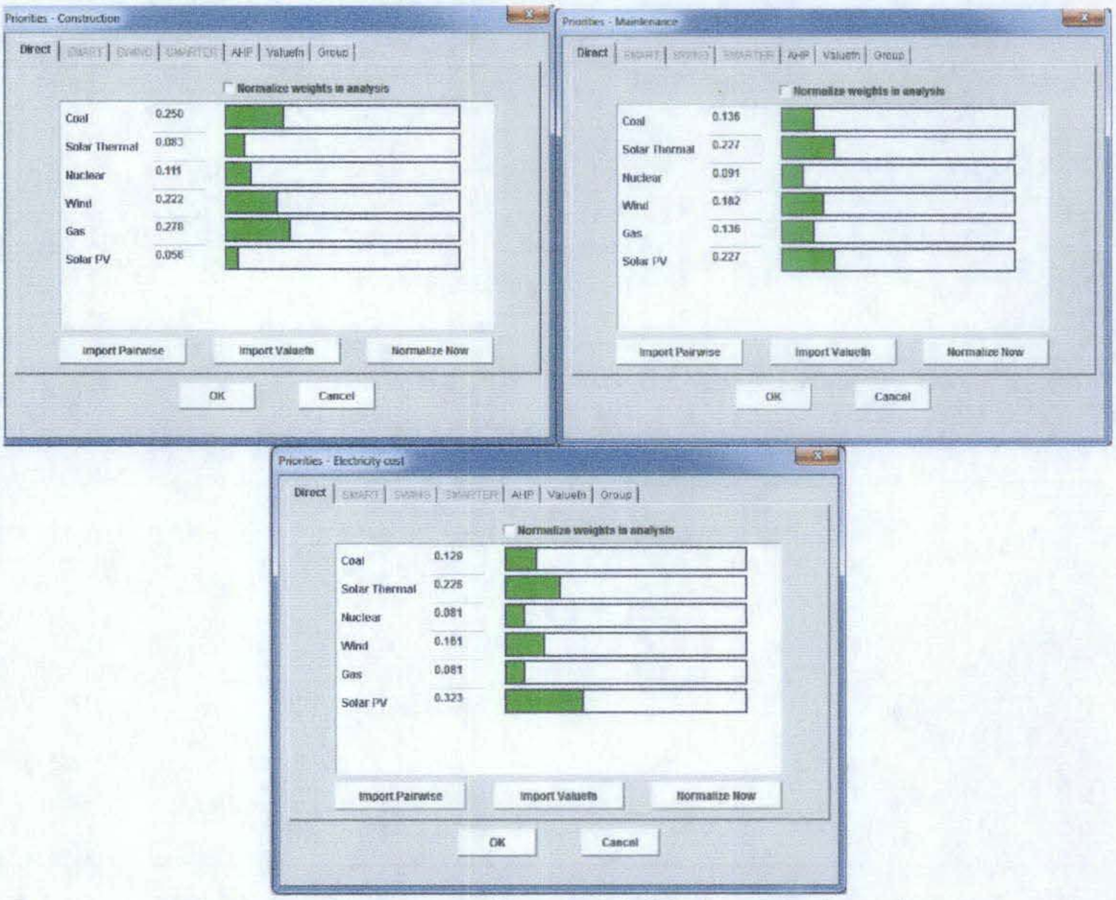


Figure 23: the expenses direct weighting for each alternative

In Figure 23 it shows the direct weighting of both the fuel coss and fuel availability which are the 2 subcriteria's of the Fuel criteria.

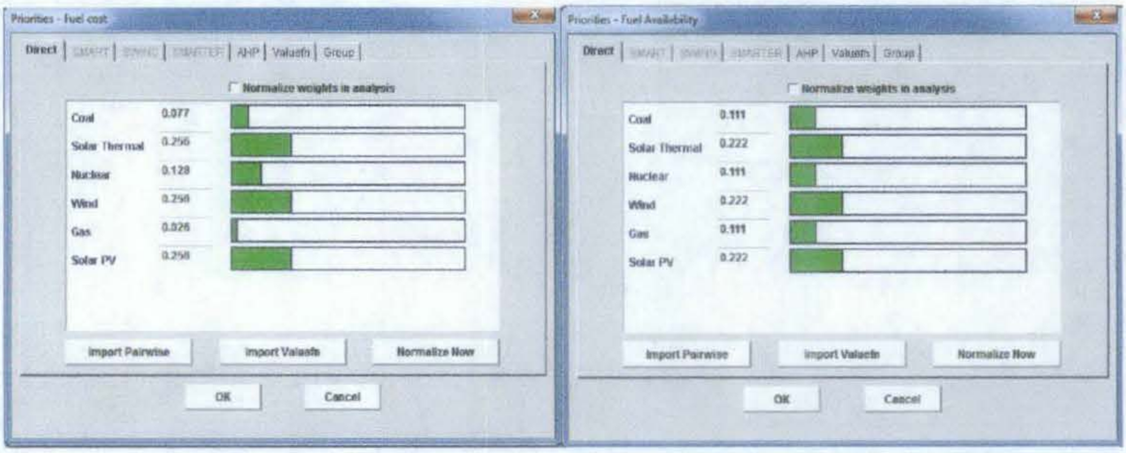


Figure 24: Direct Weighting for the Fuel for each alternative

In Figure 24 the Direct weighting of both efficiency and the CO2 emission is shown as the 6 power plants alternatives are being weighted

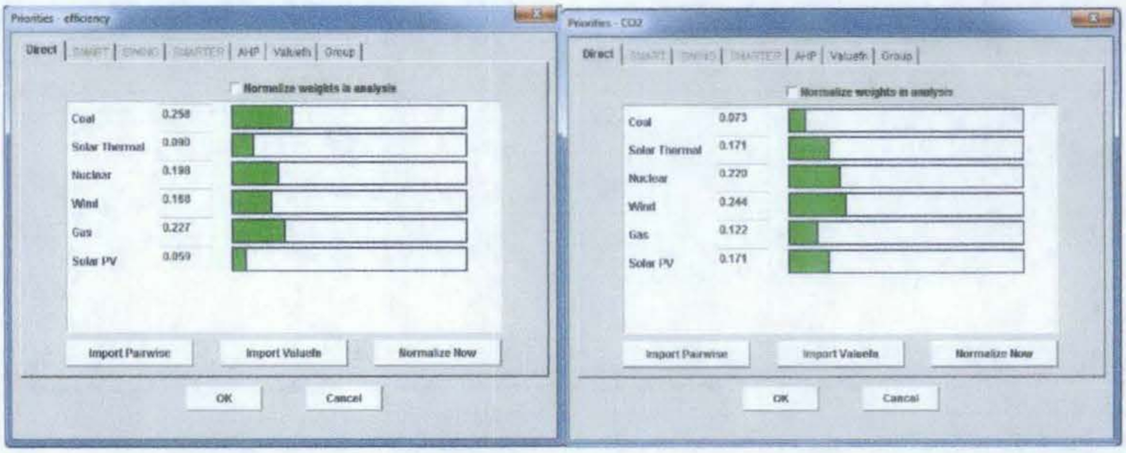


Figure 25: Direct Weighting for the Environmental criteria's for each alternative

Now after assigning the scores of the subcriterias or each criteria we can run the model and get the graphs to show the best Power Plant. to show the results in the Web-HIPRE software click on *Analysis button* and then click on *composite analysis*. Then the graphs will come out like shown in Figures 26 which shows the composite priorities of the my 3 criteria's and in Figure 27 it shows the composite priorities of my 7 subcriteria's. a Text form of results is also shown in Figure 28.

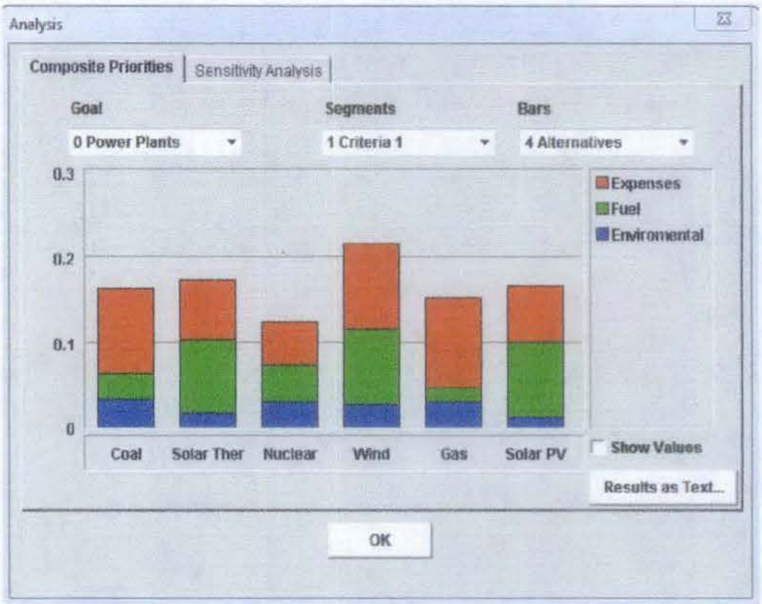


Figure 26: Composite Analysis for the first criteria

Figure 27: Compsite Analysis for the second criteria

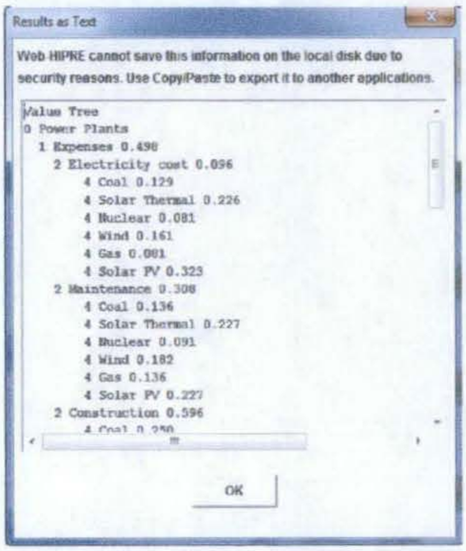


Figure 28: Results in the form of text

From the above graph and results it is obvious that the Wind Power Plant is the best alternative compared to the others as it got no fuel costs, very low CO2 emission, and a low operation costs. The overall value shows that it's the best alternative.

After getting the graph's we did the sensitivity analysis but still our results didn't change much as the Wind Power plants is still the best alternative in all the Expenses criteria, fuel criteria and the environmental criteria as shown in Figures 28, 29 and 30.

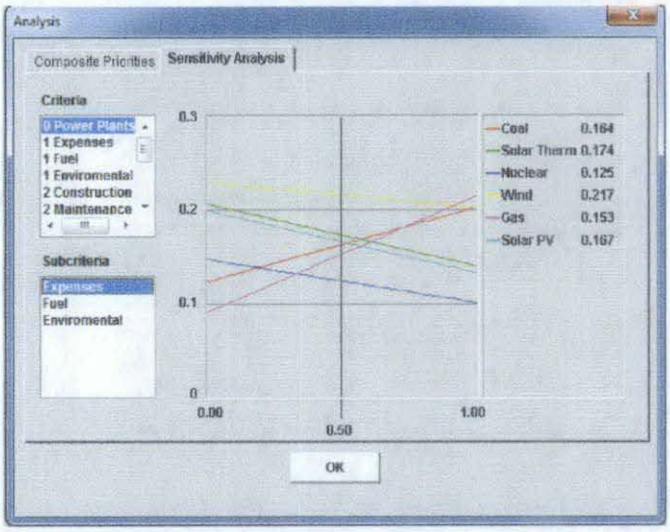


Figure 29: Senstivity Graph for the Expanses Criteria

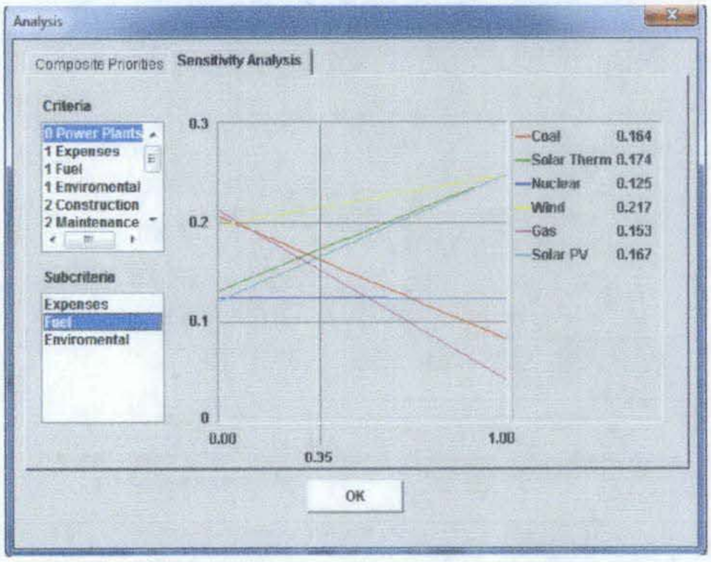


Figure 30: Senstivity Graph for the Fuel criteria

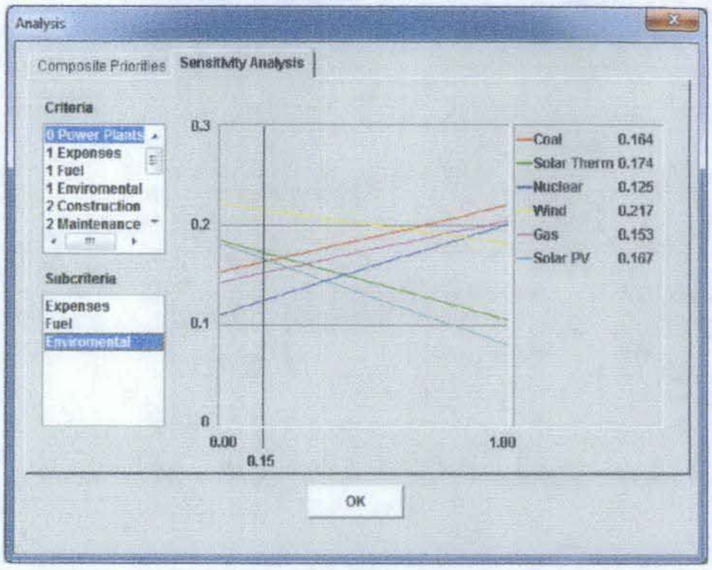


Figure 31: Senstivity Graph for the Enviromental Criterea

4.2 Discussion

Most of decisions makings are based on individual judgments. As we try to make our decision as rational as possible we need to quantify these subjective opinions into subjective values. Higher value indicates higher level of the factor or preferable values. Now you see that not only the criteria and alternatives are subjective, even the values are also subjective. They are depending on you as decision maker.

From the results obtained we can see how I used the Web-HIPRE software to apply my methods of MCDM to help the process of selection of a power plant and dividing the main Topic into criteria's and subcriteria's then sizing and weighting the criteria's and using the MCDM methods to finally get the final result showed that the Wind Power Plant is the most suitable power plant for the Port Dickson Power Plant. As the wind power plants needs very low maintenance costs and its operation costs is not as expensive as the other power plants, also its efficiency and electricity costs are very reasonable. The selection of a Power Plant depends on several criteria's like the operation costs, maintenance costs, electricity costs, fuel costs, fuel availability, efficiency and CO2 emission. After applying the MCDM methods we got some results which is easy to understand and easy to interpret and help us reach a fast conclusion.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the project sets a target of understanding and studying the functions and different types and classifications of the Multi Criteria Decision Making (MCDM) and learns how to apply it on the date given to help choosing the best power plant by comparing them using the MCDM methods, applying MCDM methods was used to get the expected results from the user. The software used was the Web-HIPRE software, the detailed study of it is done and MCDM is applied for the selection of power plants. This software simplify a complex situations in order to choose and make up your mind about a certain criteria, the software facilitates this process for you

From the Results obtained I have concluded that the best 2 methods to compare my alternatives are the AHP method and the Sensitivity Analysis and use them to compare my alternatives which my results shown that the most suitable power plant for the Port Dickson Power Plant can be the Wind Power Plants.

5.2 Recommendation

The criteria's selected are not finalized and more criteria's can be added to the software. Also the weighting methods depend from one user to another user according to the environment and the needs of the user. So the software methods have been though in this report, you can use the same methods to compare different power plants in a different venue and also being able to add more/less criteria's as the user likes.

REFERENCES

[1] Extension of the TOPSIS method for decision-making problems with fuzzy data *G.R Jahanshahloo, F. Hosseinzadeh 2006*

[2] Weak comparability of value as a foundation for ecological economics *Joan Martinez-Alier, Giuseppe Munda, John O'Neill, 25 July 2007*

[3] Multi-Criteria Decision-Making (MCDM) retrieved May, 2011, from http://rfptemplates.technologyevaluation.com/multi-criteria-decision-making-mcdm.html

[4] Decision Analysis and Uncertainties in Planning Local Energy Systems *Espen Loken, Audun Botterun and Arne T.Holen, 11 June 2006*

[5] PROMETHEE and AHP: The design of operational synergies in multicriteria analysis.Strengthening PROMETHEE with ideas of AHP *Cathy Macharis, Johan Springael ,Klaas De Brucker, Alain Verbeke*

[6] Energy Planning retrieved from Wikipedia January 2011 http://en.wikipedia.org/wiki/Energy_planning

[7] Power Plants retrieved from Wikipedia January 2011 http://en.wikipedia.org/wiki/Power_station

[8] Power Plants: Characteristics and Costs *by Stan Kaplan, 2008*

[9] natural Gas power plants retrieved from Wikipedia January 2011 http://en.wikipedia.org/wiki/Natural_gas_power_plant#Gas_turbine_plants

[10] Wind Power Plants retrieved from Wikipedia February 2011 http://en.wikipedia.org/wiki/Wind_power_plant

[11] Thermal solar panels retrieved from Wikipedia February 2011 http://en.wikipedia.org/wiki/Thermal_solar_panel

[12] Port Dickson Power Station Rehabilitation Project Report, *2008*

[13] Port Dickson Power Plant retrieved from March 2011 http://www.simedarbyenergyutilities.com/Port_Dickson_Power_Bhd_(PDP)_.aspx

[14] Web-HIPRE Global Decision Support System retrieved August 2nd, 2010 from http://www.hipre.hut.fi/Help.html

[15] "Web-HIPRE - Global decision support by value tree and AHP analysis" research paper by *Jyri Mustajoki and Raimo P. Hämäläinen, December, 17th, 1999*

[16] Web-HIPRE home page http://www.hipre.hut.fi/

[17] Use of multicriteria decision analysis methods for energy planning problems *by Espen Loken, 2005*

[18] Multi-criteria decision analysis (MCDA) retrieved July 23rd, 2010 from http://en.wikipedia.org/wiki/Multi-criteria_decision_analysis

[19] Multi-criteria assessment of new and renewable energy power plants *by Naim H. Afgan, Maria G. Carvalho 2001*

[20] Power Distribution Planning Using Multi-Criteria Decision Making Method *By Sandeep Chakravorty , Smarajit Ghosh, 2009*