TECHNOLOGY ASSESSMENT BY APPLYING FUZZY HIERARCHICAL PROCESS FOR PRIORITY RANKING OF DIFFERENT POWER GENERATION METHODS IN BANGLADESH

By

A.K.M. GOLAM BAHARUL

Master of Science in Management of Technology (M.Sc. in MOT)

ISNSTITUTE OF APPROPRIATE TECHNOLOGY

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

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CERTIFICATE OF APPROVAL

The thesis titled "**Technology Assessment by applying Fuzzy Hierarchical Process for priority ranking of different Power Generation Methods in Bangladesh**", submitted by A.K.M. Golam Baharul, Student ID: 0413292029, session April 2013 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Management of Technology (M.Sc. in MOT) on January 17, 2016.

1. Dr. M. Kamal Uddin — Chairman
Professor
Institute of Appropriate Technology (IAT)
BUET, Dhaka.
(Supervisor)

2. Dr. M. Kamal Uddin — Member (Ex-Officio)
Director
Institute of Appropriate Technology (IAT)
BUET, Dhaka

3. Dr. M. A. Rashid Sarkar — Member
Professor
Department of ME
BUET, Dhaka.

4. Dr. Kazi Md. Shorowordi — Member
Associate Professor
Department of MME
BUET, Dhaka.

5. Dr. M. Shamsul Alam — Member (External)
Dean, Faculty of Engineering
Daffodil International University
(Ex-Professor, EEE, CUET)

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DISCLAIMER

I, hereby, declared that this thesis or any part of it has not been submitted elsewhere for award for any degree or diploma.

A.K.M. Golam Baharul

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ABSTRACT

The objective of this study was to construct a practical approach based on Fuzzy analytical hierarchy process (Fuzzy AHP) for Priority ranking of different Power Generation Methods in the perspective of Bangladesh. In this thesis five alternatives, five main attributes/criteria and ten sub-attributes/criteria are considered. These alternatives, attributes and sub-attributes, synthesize from experts" knowledge and judgments. Choosing the suitable alternatives of Power Generation Methods is a multi-criteria decision making (MCDM) problem. In this study, it is tried to tap the real-life modeling potential of fuzzy logic and conjugate it with the commonly used powerful AHP modeling method. Fuzzy AHP has chosen to calculate the relative global weights of each alternative in order to reduce vagueness and ambiguity of information and ranking. It shows that the proposed Fuzzy AHP model for priority ranking of different power generation method can be a useful and effective technology assessment tool for future energy generation mix planning.

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AHP	Analytical Hierarchical Process
AIR	Availability of Input Resources
APLOC	Appropriate Plant Location
BCF	Billion Cubic Feet
CFPP	Coal Fired Power Plant
CI	Consistency Index
CR	Consistency Ratio
DM	Decision Maker
EF	Economic Factor
ENVF	Environmental Factor
FAHP	Fuzzy Analytic Hierarchy Process
FY	Financial Year
Fuzzy AHP	Fuzzy Analytic Hierarchy Process/Fuzzy Hierarchical Process
GC	Generation Cost
GFPP	Gas Fired Power Plant
GIIP	Latest Estimate Total Initial Gas in Place
HPP	Hydro Power Generation Plant
ICR	Initial Cost and Royalty
IL	Impact on Life
IPENV	Impact on Physical Environment
MCDM	Multi Criteria Decision Making
NPP	Nuclear Power Plant
OFPP	Oil Fired Power Plant
PDI	Plant Design and Installation Complexity
POC	Plant Operational Complexity
POPDEN	Population Density
POPUF	Population Factor
PSMP	Power System Master Plan
RC	Random Consistency
RF	Resource Factor
SMP	Skilled Man Power

TA	Technology Assessment
TF	Technological Factor
TFN	Triangular Fuzzy Number
TM	Technology Management
WRT	With Respect To

1. INTRODUCTION

1.1 Statement of the Problem

The technology assessment, choice of technology or priority ranking of technology is generally based on a techno-economic feasibility study. The scenario at the local, as well as at the global level is changing, and that necessitates the consideration of factors, such as environmental and socio-cultural, in addition to the techno-economic factors. These lead the technology assessment to a multi criteria decision making (MCDM) situation [1]. Fuzzy analytical hierarchical/Fuzzy hierarchical process (Fuzzy AHP) is widely used to deal with decision-making problems involving multiple criteria evaluation/selection of alternatives and it has advantages in handling unquantifiable criteria and obtained quite reliable results [2].

The main aim of this research is to demonstrate an applicable way of improving evaluation tactics in complex decision problem of ranking of power generation methods (1) where there is a large number of decision makers (group decision in multi criteria decision making – MCDM), and (2) there is a need to follow human behavior, where fuzziness comes closer to reality compared to classical evaluation processes using crisp data [3].Fuzziness means uncertainty, vagueness, unsureness, ambiguity, unclearness. The second point which is very important for this study is to construct a scientific mainstream within decision making for the ranking of power generation methods. Fuzzy logic is a form of many-valued logic that deals with approximate, rather than fixed and exact reasoning[4].Compared to traditional binary logic (where variables may take on true or false values), fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true to completely false. The fuzzification of qualified MCDM methods going back to Zadeh‟s argumentation concerning fuzzy sets, first published in 1965 [5].One widely used method which can handle both group decisions and fuzziness, qualitative and quantitative data is the fuzzy analytical hierarchical process (Fuzzy AHP) , a further development of Tomas Saaty‟s widely used AHP technique [6].

Bangladesh is a country of 160 million people with a land area of 147,570 sq km, has shown tremendous economic growth in recent years. A booming economic growth, rapid urbanization, escalated industrialization and development have increased the country's demand for electricity. Presently, 68% of the total population (including renewable energy) has access to electricity and per capita generation is 348 KWh, which is very low compared to other developing countries .To increase/maintain the GDP growth, the generation of electricity is must to meet the growing demand. The installed electric generation capacity of Bangladesh was 10289 MW in January, 2014; only three-fourth of which is considered to be „available". The Government has prepared Power System Master Plan 2010 to realize the goal to provide access to electricity to all. According to the Power System Master Plan (PSMP-2010) study, the maximum demand in 2015, 2021 and 2030 would be about 10,000 MW, 19,000 MW and 34,000 MW respectively. To meet the demand with reasonable reliability, generation capacity will be increased to 24,000 MW and 39,000 MW by the year 2021 and 2030 respectively [7-11].

The present demand of Bangladesh is 1.3 million tons of crude oil and 2.7 million tons of refined petroleum products per annum in addition to 2 (two) million tons of diesel to feed oil-based power plants being planned and built all around the country[10]. The coal mine of the country is in the development stage, the reserve of which is about 3.3 billion tons[10]. But electricity generation from coal has adverse effect on environment. On the other hand, to make matters worse, natural gas production of Bangladesh is expected to decrease in future [12].

In this complex energy/power situation of the country, Bangladesh plans to have two 1000 MW Russian nuclear power reactors in operation from 2020 which will be envisaged up to 5000 MW by 2030. But, in 2013, a group of Bangladeshi scientists and the global Diaspora voiced profound concern over the safety, technology and economic viability of the nuclear plant [13].

Hence, Priority ranking of power generation methods: Gas, Coal, Hydro, Oil and Nuclear by using Fuzzy AHP tools would give a result where fuzziness comes closer to reality. So, the outcome of this research contributes to take decision by the decision makers (DMs) about which type of power generation method will be given preference at what level to increase the power generation to meet theessential futuredemand in the perspective of Bangladesh.

1.2 Research Objectives

The objectives of this thesis are:

i. To apply the Fuzzy analytical hierarchical (Fuzzy AHP), a strong Technology Assessment (TA) tool for Multi-Criteria Decision Making (MCDM) problem to construct the priority rank of different power generation methods for future power generation mix planning in the perspective of Bangladesh with some recommendations.

ii. To apply the Delphi Technique for finding out the related main attributes/variables, sub attributes/variables to construct Fuzzy hierarchical structure and a structured questionnaire for eliciting expert opinion.

iii. To brief review the present power generation mix scenario of Bangladesh.

1.3Outline of Methodology

The synopsis of methodology is give below:

i. In this study, data finds from Bangladesh Power development Board (BPDB), Energy and Mineral Resources Division; Power Division; Ministry of Power, Energy and Mineral Resources will be considered as the primary data regarding power/energy scenario in Bangladesh.The data will also be taken from the internet, books, journals, related studies/articles and other sources of information.

ii. Throughout this study, a brief review of power generation scenario of Bangladesh, AHP and Fuzzy AHP theories will be reviewed.

iii. A structured questionnaire will be prepared by the ways of interviews and interaction of relevant experts, observation and literature review by following the principles of Delphi Technique.

iv. An expert opinion will be elicitedasa General Intuitive Method (GIM) of Technology Assessment based on the structured questionnaire both from the academicians and professional of the relevant field.

v. An algorithm flow diagram, hierarchical decomposition structure will be constructed for Fuzzy AHP analysis.

vi. CGI AHPsoftware, Excel/ will be used for Fuzzy AHP rigorous mathematical calculation.

vii. Finally, through rigorous mathematical calculation ranking of different power generation methods/alternatives will be done based on global weight in the perspective of Bangladesh.

1.4 Validation of methodology

Fuzzy AHP is widely used to deal with decision-making problems involving multiple criteria evaluation/selection of alternatives and it has advantages in handling unquantifiable criteria and obtained quite reliable results. The planning of energy generation mix for Bangladesh is also a multi criteria decision making (MCDM) problem and in this study it has been used the Fuzzy AHP tool for the priority rank of different power generation methods for future power generation mix planning in the perspective of Bangladesh.

There are several examples of research and application of the fuzzy AHP for MCDM problem, amongst others, A Fuzzy AHP Approach for Selection of Measuring Instrument for Engineering College Selection[14], Applying Fuzzy analytic hierarchy process to evaluate success factors of e-commerce[15], Using fuzzy analytical hierarchy process (AHP) to evaluate web development platform[16],Using fuzzy multi criteria decision making approach for ranking the web browsers [17],Evaluating IT/IS investments: A fuzzy multi-criteria decision model approach [18],Fuzzy AHP Assessment of Water Management Plans [19],Developing a Fuzzy model for assessment and selection of the best idea of new product development[20], Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard[21],Decision Aid for Planning Local Energy Systems: Application of Multi-Criteria Decision Analysis [22],Application of Multicriteria Decision Making to the Evaluation of New Energy System Development in Taiwan [38], Multiple Criteria Decision Making Techniques Applied to Electricity Distribution System Planning [39],Pre-Feasibility MCDM Tools to Aid Communities in Prioritizing Local Viable Renewable Energy Sources [44], Fuzzy AHP group decision analysis and its application for the evaluation of energy sources [46].So, the Fuzzy AHP is a widely used recognized tool for planning and decision making of MCDM problem research. The brief description of some of this research work has been given in literature review.

1.4.1 Data Validation

The collected data from the experts have been validated through cross checking and the consistency of each matrix has been checked. If the collected data of someone was found inconsistence, the data has been collected again and again until the matrix was found consistence.

1.5Contribution of the Thesis

The purpose of this study is to develop a scientific framework and using it for priority ranking of different power generation methods in the perspective ofBangladesh. The main contributions of the thesis are as follows:

1. Technology assessment is an important component for effective technology management (TM). This is truer of energy systems in developing countries. But in Bangladesh such kind of research is very limited or absent. This research is a small initiative of this new research era of Bangladesh.

2. In this study it is tried to find out the requirement specification for an MCDM based energy generation mix planning framework of Bangladesh withtransparent logic, elicit and aggregate the expert‟s preferences consistently, handling of uncertainties or fuzziness and result is presented in a way which is easily understandable by the Decision Makers (DMs).

3. Finally, According to the priority rank of different power generation methods which is the outcome of this researchwith less fuzziness or closer to reality, the DMs may consider about which type of power generation method will be given importance at what level for the action plan of power generation mixplanning inthe socio-cultural, economic, environmental and demographic context of Bangladesh.

1.6 Scope and Limitation of the Study

Scope:

This research focuses on the priority ranking of Nuclear, Gas, Coal, Oil, Hydro power generation methods in the perspective of Bangladesh considering related attributes/variables by Fuzzy AHP tool. The scope of the research is to describe the importance or preference of different power generation methods (Gas, Coal, Oil, Nuclear, and Hydro) for the future power generation mix planning in Bangladesh perspective with some specific scale or global weight which is easily understood by DMs.

The Delphi Technique is applied in this research work for finding out the related main attributes/variables, sub attributes/variables to construct Fuzzy hierarchical structure and a structured questionnaire for eliciting expert opinion.

For constructing the Fuzzy pair wise comparison matrix, we have used the subjective/judgmental expert opinion of both academician and professional of the relevant expert to get the more accurate/reliable result. Rigorous mathematical operations have been conducted to find out the global weight of different power generation methods/alternatives for prioritization in the perspective of Bangladesh and thus tried to formulate an energy generation mix planning framework for the future action of DM.

Limitation:

In this empirical research, Fuzzy AHP analysis is applied mainly for the non renewable power generation method; as the renewable power generation has less influence over total generation in present energy generation mix of Bangladesh. The renewable energy generation method also excluded to reduce the complexity of expert‟s opinion regarding Fuzzy pair wise comparison matrix and complex mathematical calculation.

Moreover, the priority rank is calculated on the judgmental opinion of experts, in this case the refinement/ accuracy of the ranking also depends on the foresightedness and thoroughness of the experts. Lack of foresightedness and thoroughness expertise may leads to result accordingly.

2. LITERATURE REVIEW

2.1 Power Generation Methods

Method is an established, habitual, logical or prescribed practice or systematic process of achieving certain ends with accuracy and efficiency, usually in an ordered sequence of fixed steps. Technology is the collection of techniques, skills, methods and processes used in the production of goods or services or in the accomplishment of objectives, such as scientific investigation. Technology can be the knowledge of techniques, processes, etc. or it can be embedded in machines, computers, devices and factories, which can be operated by individuals without detailed knowledge of the workings of such things.

The term "power generation methods" is used in a variety of scientific settings and contexts, and it is difficult to find a common definition of the term. This thesis will use the term "power generation methods" to refer to power-generation by fuel type/primary energy source, i.e. what type of fuel/primary energy source should be used for energy generation mix in future planning for the uninterrupted access to necessary energy services of the people of Bangladesh.

2.2 Power Generation Planning

Power generation planning can be defined as "the process of choosing the fuel/primary sources and technologies needed for power generation to satisfy community needs" [22]. Power generation planning can be performed on many levels; everything from a national level to a very local level. However, this thesis will focus on planning of Power generation for the national level.

2.3 Decision Modeling

In this thesis it is tried to formulate the modelling regarding power generation decision in the perspective of Bangladesh. Modelling a decision is a way to bring order to the unstructured chaos of the usual decision making situation[23]. A model is a representation of an object or idea that helps to better understand it. By going through the modelling process it can be clarified in someone"s mind and to other people what are the important driving forces in the decision and the alternative courses of action that are available.

By building a model it can be overlooked to some crucial aspect of the decision. Specifying the alternatives inspires to look for other alternatives that may not be so obvious.

The model itself will remain as a record of the decision, which can be revisited later, so someone can observe what was good and what could be improved to make better decisions in the future. By fully documenting all the elements of the model it can defend the decisions and prevent from being overruled.

2.3.1 Definition of related terms

MCDM: Multi-Criteria Decision Making; The use of methods that help people make decisions according to their preferences in cases characterized by multiple conflicting criteria.

Decision-maker (DM): The person or entity that is responsible for making a decision. The DM might be an individual, a small, homogenous group with common goals, a large group representing different elements of an organization, or a number of highly diverse interest groups.

Alternative: Projects, candidates, and investment plans, among which a choice has to be made. The term is often used for actions that are mutually exclusive in terms of implementation. There can either be a finite number of explicitly defined discrete alternatives or implicitly defined continuous alternatives.

Optimal/ideal alternative: An alternative that results in the maximum performance value for each of the objective functions simultaneously [24]. An ideal alternative will very seldom be found in the real world.

Criterion: A tool constructed for the evaluation and comparison of alternatives and the degree to which they achieve objectives. The criteria offer comprehensive and measurable representations of the DM"s preferences.

Quantitative and Qualitative criterion: A criterion that can be measured on a clear, concrete defined scale is called quantitative analysis. Qualitative criterion is one for which evaluations cannot be made on a numerical basis. Instead, a verbal scale or an ordinal ranking scale can be used.

Attribute: A quantitative measure of performance, used to evaluate directly or indirectly the degree to which the objectives are achieved. A good attribute both defines precisely what the associated objective means and serves as a scale to describe the consequences of the alternative.

2.4 Description of MCDM

An optimal solution is always the primary goal in decision-making. Unfortunately, a true optimal solution only exists if considering a single criterion. In most real decision situations, basing a decision solely on one criterion is insufficient. Often, it is necessary to plan systems where several conflicting and non-commensurable objectives need to be considered. Especially the cost criterion often comes into conflict with other criteria. This can be called "the eternal problem of limited resources and unlimited needs" [25].
The conventional approach to energy planning is to search for the minimum cost solution that meets both present and future power and energy demands. Other criteria, such as emissions, environmental, social, safety, technical skill and the reliability are given monetary values, and included in the cost criteria. Alternatively, they may be considered only as constraints, so that all alternatives that do not meet a minimum/maximum performance target for all other objectives are disregarded i.e., arbitrary boundary choices are used as substitutes for all but one objective. This classical optimization will provide a solution. However, in many cases the optimization will not provide the "best solution". The use of constraints is not particularly helpful in evaluating alternatives, since in reality, there is often more flexibility than is indicated by absolute constraints. For instance, if an alternative is not able to meet the performance target for one of the more insignificant criteria, the alternative will be eliminated, even though the alternative might be among the best for all other criteria. Actually, the use of constraints restricts the most important criterion because the approach guarantees that targets for the less important criteria are first satisfied, before there is any consideration of the criterion considered to be the most important. New regulations in the energy market – particularly the increased focus on environmental impacts from energy systems – have led to more interest in systematic methods for decision aid. A better planning approach is to balance the various criteria, either explicitly or more or less unconsciously, to try to find an

acceptable compromise solution. Problem solving that involves complex systems but that does not include the use of any specific methodology might distort the final results. Without the help of tools, decision-makers (DMs) may appear to focus only on a small subset of the criteria, formulate their opinions based on insufficient information, or miscalculate with regard to uncertainties [26].

Multi-criteria decision-making" (MCDM) is a generic term for the use of methods that help people make decisions according to their preferences, in cases characterized by multiple conflicting criteria. Another term that is frequently used is „multi-criteria decision analysis (or „decision aid") (MCDM). The reason for using the second term is to emphasize that the methods themselves cannot make the actual decisions, i.e., they cannot substitute for a DM.

It can be said that the use of MCDM is a way of dealing with complex problems by breaking them into smaller pieces [27]. After weighing some considerations and making judgments about smaller components, the pieces are reassembled to present an overall picture for the DMs. In this way, choices based on intuition and experience alone can be substituted by a mathematical model.

2.5 Classifying MCDM Methods

A lot of MCDM methods have been proposed over the years. The main idea in all of them is to be able to compare alternatives that have different performance levels for various criteria and to create a more formalized and better-informed decision making process. However, none of these methods can be considered applicable in all decision-making situations. There are too many different decision situations, and there will always be DMs that are not able to provide the necessary information required to use the hypothetical „perfect" method [28, 29]. The various methods differ in many areas: theoretical background, type of questions asked, and type of results given [30]. Some methods have been created particularly for one specific problem, and are not useful for other problems. Other methods are more universal, and many of them have attained popularity in various areas. All methods strive to create a more formalized and better-informed decision-making process.

There are many different ways to classify existing MCDM methods. One common classification, as found in [31], is to distinguish between what is commonly called multi-objective decision-making (MODM) (also called multiple criteria optimization (MCO)) and multi-attribute decision-making (MADM). MODM are methods for problems formulated in the context of a mathematical programming framework. In this type of problems, attribute values must be determined in a continuous domain. Accordingly, the alternatives are only implicitly defined, and there is an indefinite number of alternatives. MADM, on the other hand, refers to methods suited for solving multi criteria problems where the alternatives are explicitly defined and discrete, i.e. there are choices among a limited number of pre-specified alternatives. This thesis will focussolely on discrete problems, and accordingly solely on MADM methods.

Belton and Stewart used another classification for MCDM methods [32]. This classification is also used in this review. According to Belton and Stewart, there are three broad categories of MCDM methods:

- Value-measurement models
- Goal, aspiration and reference-level models
- Outranking models (the French school)

The following sections describe the main characteristics of the three categories, and present some of the most well-known methods in each group.

2.5.1 Value-measurement methods

In value-measurement methods, a numerical value (or score) V is assigned to each alternative. These values produce a preference order for the alternatives such that a is preferred to b ($a > b$) if and only if $V(a) > V(b)$. When using this approach, the DM defines a set of relevant criteria for the planning problem. For each criterion i, a partial value function $v_i$must be established that reflects the performance on the considered criterion i. The partial value function must be normalized to some convenient scale (e.g. 0–100). The various criteria are given weights that represent their partial contribution to the overall score, based on how important each criterion is for the DM. The criteria weights should indicate how much the DM is willing to accept in the trade-off between criteria. Because poor performance values on some criteria can be compensated by high performance values on other criteria, the value-measurement methods are also known as compensatory methods [33]. The use of value-measurement methods assumes that the DM is able to give precise answers to a wide range of preference- elicitation questions.

2.5.2 Goal, aspiration and reference-level methods

The second category of MCDM methods is composed of goal programming (GP), aspiration- level and reference-level methods. GP is often used as a common abbreviation for all of these approaches, and this simplification is also used in this thesis. When using GP approaches, we try to determine the alternatives that in some sense are the closest in achieving a determined goal or aspiration level. Often the GP approach is used as a first phase of a multi-criteria process where there are many alternatives. In other words, GP is used to filter out the most unsuitable alternatives from the analysis in an efficient way. Although most GP methods can be generalized for use in discrete decision problems, these methods have been developed for continuous decision problems. Accordingly, the GP approach is only briefly presented in this thesis.

From a mathematical perspective, we can say that the idea behind GP methods is to solve the inequalities $z_i + \delta_i \geq g_i$ for each criterion i, where z_i is the attribute values, δ_i is the non-negative deviational variables and g_i is the goals. The goal might be the ideal value or a desirable, but realistic, level of performance. However, DMs often have a problem defining realistic targets. The goal of the methods is to find a feasible solution that minimizes the vector of deviational variables. If it is possible to find a solution where $\delta_i = 0$ for all i, this will be the recommended solution. However, in most cases, such a solution cannot be found, and instead, we must look for another solution.

2.5.3 Outranking methods

In outranking methods, it is assumed that the DM is not able to/willing to define tradeoffs between criteria. Accordingly, in these methods it cannot be assumed that a poor performance value in one criterion can be compensated by a sufficiently good performance values in another criterion, as in the value-measurement methods.

In the outranking approaches, alternatives are compared pair-wise to determine which of the two is preferred for each criterion. The result from the comparison is an outranking relation between the alternatives. When aggregating the outranking relations for all relevant criteria, the model determines to what extent one of the alternatives can be said to outrank another. It can be said that an alternative a outranks an alternative *b* if there is enough evidence to conclude that is at least as good as *b*, and no strong argument to prove the contrary, when taking all criteria into account. The methods based on this way of thinking are often called the French (or European) school of multi-criteria decision-making.

The outranking approach is based on less restrictive assumptions than value measurement methods, and requires less precise input in terms of describing criteria and preferences [9]. Accordingly, these methods may correspond better to the way DMs really think. However, a major drawback is that many of the necessary inputs might feel non-intuitive for DMs, particularly the indifference and strict preference thresholds.

2.6 Choosing a MCDM method

A variety of experiments have shown that choice of method might have a significant influence on the decision outcome. According to Hobbs et al. [34], the choice of method might even matter as much or more than which person that are using the methods. There are many possible explanations for these differences; the DM may not fully understand the method, or some methods may not able to provide a valid representation of the DM‟s preferences.

Choosing a MCDM method means that choosing compensation logic. This might be a difficult choice; thus, there are many criteria to consider [35]. Among the most important is the validity, i.e. that the method measures what it is supposed to measure. Different methods are likely to give different results, so a method that reflects the user‟s „true values‟ as accurately as possible should be chosen. However, it is important to be aware that different people have different ways of thinking about and expressing values. Accordingly, the method that is most valid for one DM is not necessarily most valid also for other DMs. Another important property is the method‟s appropriateness, i.e. that the method is compatible with the accessible data and that the method can provide DMs with all the information they need. The MCDM method should also be easy to use and easy to understand, even for non-experts. If the logic behind the method is not transparent, a DM may perceive the methodology to be like a black box. The result may be that the DM does not trust the recommendations from the method. In that case, it is meaningless to spend time applying the MCDM method.

In practice, the choice of method mostly depends on the preferences of the DM and the analyst. Accordingly, the most important criteria for the choice of MCDM method is often familiarity and affinity to a specific method. Accordingly, instead of looking for the most appropriate method, the decision problem is adapted so that it fits to the DM"s or analyst"s favorite method. The result is that important limitations and underlying assumptions of the methods often are often ignored.

Choosing among the MCDM methods that exist can be said to be a multi-criteria problem in itself. Each of the methods has its own advantages and drawbacks, and it is not possible to claim that any one of the methods in general is more suitable than any other. However, some methods are more suitable if uncertainty is a key problem, while other methods are more suitable if conflicting values are most important [36]. It is important to realize that the use of different methods will most probably give different recommendations. This should not lead to the conclusion that there is anything wrong with any of the methods. It just means that the different methods work in different ways.

2.7 MCDM and Energy Planning – a Review

Many applications of MCDM methods for energy-planning problems have been published in recent years. This section presents some examples. These examples are not meant to form a complete review of all work that has been conducted in this sector.

2.7.1 Value-Measurement Methods

Value-measurement methods have been used in various energy-planning applications, particularly for choosing/ranking energy strategies or technologies. Some of the examples are evaluating alternative electricity supply strategies and expansion planning, using the AHP [37, 38], a method similar to AHP, SMART [39] or methods based on MAUT [40]. MAUT has also been used in energy-supply optimization, while AHP has been used for energy-policy analysis [41, 42], energy-resource allocation [43] and pre-feasibility ranking of alternative local renewable energy sources [44].

The advantages and shortcomings of the AHP method have been discussed byRamanathan and Ganesh [43]. They attributed the AHP method‟s popularity to its simplicity, flexibility, intuitive appeal, and its ability to handle both quantitative and qualitative criteria in the same framework. However, the method also has some drawbacks. According to, the main disadvantage is that AHP is very time-consuming when the number of alternatives and/or criteria is large, as is often the case in energy problems. Another, often criticized problem with the AHP method, for instance [45], is the use of the ratio scale and in particular the conversion from verbal to numerical judgments given by the fundamental scale. It appears that the conversion table tends to overestimate preference differences.

2.7.2 Fuzzy AHP Methods

Fuzzy Logic is a type of logic that recognizes more than simple true and false values. With fuzzy logic, propositions can be represented with degrees of truthfulness and falsehood. This Fuzzy Logic is also used with the combination of AHP [46], for energy planning optimization.

2.7.3 Combination of methods

Some researchers have tried to combine the use of different MCDM methods. AHP has been a particularly popular choice for combining with other methods. The combination of Fuzzy Logic and Saaty‟s analytic hierarchy process is the very good choice to come close to reality and human cognitive behavior in the MCDM problem [14-21].

A proper combination of two (or more) methods might be a very good approach. This kind of integration can make use of the strengths of both methods. Moreover, even though both methods have some limitations, their limitations might be complementary.

2.8 Use of Fuzzy AHP Tool- Brief Review

As the Fuzzy AHP tool can handle fuzziness, group decisions, quantifiable data, unquantifiable data, so it should be considered a strong assessment tool for the MCDM problem. There are several examples of research and application of the fuzzy AHP for MCDM problem in priority ranking. Some of them are described below.

A Fuzzy AHP Approach for Selection of Measuring Instrument for Engineering College Selection [14]; in this study, it is shown that the Analytic Hierarchy Process (AHP) is a mathematical technique for multi-criteria decision-making. Complex problems or issues involving value or subjective judgments are suitable applications of the AHP approach. „Factors considered for the selection of Undergraduate Engineering Institution by the students‟, is the research topic of interest. It involves a number of qualitative judgments based on multi-criteria at multi-levels and can be addressed using AHP. Students‟ opinions are collected in AHP using pair wise comparisons. As the number of alternatives increases, the number of comparisons increases enormously. Hence the selection of a proper measuring instrument that will reduce the data collectionefforts without loss of reliability of measurement is very important.

Applying Fuzzy analytic hierarchy process to evaluate success factors of e-commerce [15]; in this study it is revealed that with the fast development of the E-commerce, it becomes critical to set up an E-commerce Evaluation criteria system. Fuzzy Analytic Hierarchy Process is a new multi-criteria evaluation method evolved from Saaty's AHP. This paper aimed to find out the key factors that affect success in E-commerce using fuzzy AHP, and give an evaluation method for E-commerce in order to help researches and managers to determine the drawbacks and opportunities.

Using fuzzy analytical hierarchy process (AHP) to evaluate web development platform[16]; in this study it is tried to find out that with the increasing importance and the role that websites play in all aspects of life, more and more web development projects are being undertaken by companies. One of the key decisions in which both short-term and long-term success of the project depends is choosing the right development platform. Its criticality can be judged by the fact that once a platform is chosen, one has to live with it throughout the software development life cycle. The entire shape of the project depends on the language, operating system, tools, frameworks etc., in short the web development platform chosen. In addition, choosing the right platform is a multi-criteria decision making (MCDM) problem. We propose a fuzzy analytical hierarchy process model to solve the MCDM problem. We try to tap the real-life modeling potential of fuzzy logic and conjugate it with the commonly used powerful AHP modeling method.

Using fuzzy multi criteria decision making approach for ranking the web browsers [17]; in this study it is found that Internet users need methods to ascertain web browser performance in a simple manner. The objective of this study was to construct a practical approach based on fuzzy analytical hierarchy process for selecting the best web browsers. In this paper five alternatives and five criteria are considered. These alternatives and criteria, synthesize from experts" knowledge and judgments. Fuzzy AHP has chosen to calculate the relative weights of selecting methods in order to reduce vagueness and ambiguity of information and ranking. It shows that the proposed fuzzyAHP model for selecting the web browsers can be a useful and effective assessment tool.

Evaluating IT/IS investments: A fuzzy multi-criteria decision model approach [18]; in this study it is described that IT/IS represents a substantial financial investment for many organizations. Whether or not to invest in new IT/IS is, therefore, a difficult decision. Simply considering human resource cost saving criteria is not enough, especially when a corporation has had many information systems. What kind of criteria should we consider when we evaluate IT/IS? How can a new IT/IS project be evaluated in an easy, cost-effective, and collective manner? We need a tool that will help decision-makers evaluate potential new investment projects. Apart from evaluating the new project per se, its compatibility and ability to integrate with an existing IT portfolio must also be considered. Hence, we propose a new approach based on the fuzzy multi-criteria decision model (FMCDM), featuring a 2-stage evaluation process with 26 criteria for IT/IS investment. All stakeholders in a corporation can decide the relative weights they give to the criteria when they evaluate a new IT/IS project by using linguistic values. Experts can also use linguistic values to evaluate all candidates easily. Only an Excel worksheet is needed to obtain an evaluation result. It is cost-effective and efficient. A case study has been performed to show how this model can be used and discuss the results.

Fuzzy AHP Assessment of Water Management Plans [19]; There are two mainstreams when using the analytic hierarchy process (AHP). One is the standard applications of crisp distributive and ideal mode versions. The other is characterized by fuzzification of the AHP methodology and by attempts to better tackle inherently uncertain and imprecise decision processes with quantitative and qualitative data. The latter is characterized by different approaches to fuzzificating the decision problem; the way of conducting judgment and evaluating process; and finally, in synthesizing the results and manipulating fuzzy numbers to devise priorities for the decision alternatives. This paper presents a fuzzy methodology for solving fully structured decision problems with criteria, sub-criteria and alternatives. It follows the logic of AHP in a simple and straightforward manner, efficiently aggregates criteria and sub-criteria into unique hierarchical level and applies a total integral method for comparing decision alternatives. The proposed methodology has been used for the assessment of water management plans in part of the Paraguacu River Basin in Brazil.

Developing a Fuzzy model for assessment and selection of the best idea of new product development[20]; in this study it is described that this paper introduces a model for evaluating and prioritizing new products development ideas. As the environment of decision making includes full of ambiguities and uncertainties, a fuzzy multi-criteria decision making model is applied to evaluate and prioritize the ideas based on the criteria. To validate the proposed mode, the results of the proposed model are compared with the results of applying the traditional AHP model in a manufacturer of Automobile parts. The comparison indicates that applying the proposed model would lead to more reliable and compatible results than the uncertain environment of decision making process.

Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard[21]; an enterprise resource planning system (ERP) is the information backbone of a company that integrates and automates all business operations. It is a critical issue to select the suitable ERP system which meets all the business strategies and the goals of the company. This study presents an approach to select a suitable ERP system for textile industry. Textile companies have some difficulties to implement ERP systems such as variant structure of products, production variety and unqualified human resources. At first, the vision and the strategies of the organization are checked by using balanced scorecard. According to the company‟s vision, strategies and KPIs, we can prepare a request for proposal. Then ERP packages that do not meet the requirements of the company are eliminated. After strategic management phase, the proposed methodology gives advice before ERP selection. The criteria were determined and then compared according to their importance. The rest ERP system solutions were selected to evaluate. An external evaluation team consisting of ERP consultants was assigned to select one of these solutions according to the predetermined criteria. In this study, the fuzzy analytic hierarchy process, a fuzzy extension of the multi-criteria decision-making technique AHP, was used to compare these ERP system solutions. The methodology was applied for a textile manufacturing company.

2.9 Decision-Making Techniques

When the benefits of actions are unpredictable, when relationships between variables may be not only non-linear and stochastic but also actually unknown, the principle of standard optimization for decision-making will not help much. This is exactly the situation we face in the world of today.

Decision-making can be considered as the choice, on some basis or criteria, of one alternative among a set of alternatives. A decision may need to be taken on the basis of multiple criteria rather than a single criterion. This requires the assessment of various criteria and the evaluation of alternatives on the basis of each criterion and then the aggregation of these evaluations to achieve the relative ranking of the alternatives with respect to the problem. The problem is further compounded when there are several or more experts whose opinions need to be incorporated in the decision-making. Lack of adequate quantitative information leads to dependence on the intuition, experience and judgment of knowledgeable persons called experts.

It can be defined a generic decision-making problem as consisting of the following activities [47]:

- Studying the situation
- Organizing multiple criteria
- Assessing multiple criteria
- Evaluating alternatives on the basis of the assessed criteria
- Ranking the alternatives
- Incorporating the judgments of multiple experts

2.10 Multi-Criteria Decision Making Problems

Making decisions is part of human life. Nevertheless, making a good decision is not always easy in the situation of today‟s world. This is mainly because there are many contributing factors (multiple criteria) in a problem. Even worse, many of them involve multiple objectives (multiple inputs, multiple outputs). That means the objectives of the problems in question may be conflicting with each other. On the one hand, solving such problems can entertain multiple dimensionalities. If the factors involved in such decision-making process are all quantitative in nature, the bestsolution can be obtained by evaluating a multi-attribute utility function as follows [48]:

$U_i(x_1; x_2; . . .; x_m) = k_1u_{i1}(x1) +K_2u_{i2}(x2) + .k_mu_{im}(xm);i = 1; 2; . ..; n$ (2.1)

where $U_i(x1; x2; . . .; x_m)$ is the utility function of m attributes (i.e. inputs) of the ith alternative, x_i are attributes under consideration, k_j is weighing of jth attribute such that summation of k_j is equal to 1 andu_{ij} is the effect of ith alternative related to jth attribute, that is, x_j.

Therefore, the solution to such problems is the feasible solution with the maximum or minimum value of the utility function. Subject to such setting, the quality of the solutions of such problems can be maintained relatively easily. The only concern would be to determine the scientific way to measure each input (i.e. x_i) and its effect (i.e. u_{ij}). Of course, finding a right balance between the set of weightings is also crucial as this may involve subjective judgment on the relative importance of one effect to the other effects.

On the other hand, many of the real-life problems are unfortunately not that easy to solve. This is mainly because most of them involve qualitative factors. That means they cannot be modeled mathematically as in Eq. (2.1), regardless of the aforementioned shortcomings. Therefore, how to quantify such qualitative variables is always the controversial topic, if not impossible, when solving such multiple-criteria decision-making (MCDM) problems. The controversy mainly comes from the subjective judgment of the qualitative factors, which always rely on experts‟ opinion, and is not consistently reliable. Such judgment inevitably affects the quality of the solution obtained. This is analogous in many cases to assign the weightings in Eq. (2.1).

Luckily, Saatydeveloped a ground-breaking tool to handle such MCDM problems. This is called analytic hierarchy process (AHP) [23]. The basic idea is to represent such MCDM problems by a hierarchical structure with different criteria and their sub-criteria. Those criteria or sub-criteria can be qualitative or quantitative in nature. Then, pair wise comparisons among those criteria are performed so that theweightings of the criteria with respect to the problem can then be estimated. Although experts‟ judgment is also required in this procedure, at least there is a way to ensure that the judgment is consistent by examining the consistency ratio. In addition, this approach can be used to select the best alternative based on these weightings and their relative importance to each criterion.

2.11 Brief Review of AHP

Analytic Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally developed by Prof. Thomas L. Saaty [23].The Analytic Hierarchy Process (AHP) is a revolutionary breakthrough which empowers to relate intangibles to tangibles, the subjective to the objective, and to link both to their purposes. In short, it is a method to derive ratio scales from paired comparisons. The input can be obtained from actual measurement such as price, weight etc., or from subjective opinion such as satisfaction feelings and preference. AHP allow some small inconsistency in judgment because human is not always consistent. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value.

Since there are different factors that can affect decision involving multiple judging criteria, trade-offs can always be found between different factors. The analysis will usually involve multiple objectives or criteria. AHP is a useful approach for evaluating such complex multiple criteria alternatives [48]. AHP is one of the widely used approaches to prioritize multiple factors. In order to evaluate or select an alternative, a design concept or a solution, weighted rating methods are generally used. It is a combinatorial decision analysis of quantitative and qualitative methods. The basic idea of AHP is to establish an orderly hierarchical system by T. Satty for analyzing elements of complex systems and their mutual relations. Proposed by T. Saaty, AHP has been employed to aid in many MCDM problems, particularly when qualitative criteria are involved. AHP is a useful approach for evaluating two or more competing alternatives along multiple criteria. AHP requires a decision maker to determine the relative importance of each criterion/factor by means of pair wise comparisons between the relevant criteria/factors included in the analysis. After the development of AHP, it has been employed to solve MCDM problems.

AHP analyses an MCDM problem by setting up a hierarchy of criteria and sub-criteria, which could be either quantitative or qualitative in nature. This can be done by introducing pair wise comparison between those criteria, which are assessed by professionals or experts in the corresponding area.

2.11.1 Pair-wise Comparison

The pair wise comparison is the measure of importance/preference of one attributes over another with respect to the objectives/attributes/sub attributes.
If the number of attributes is n, the pair wise comparisons are required can be calculated by:
No. of pair wise comparison = n (n-1)/2.

2.11.2 Consistency Index and Consistency Ratio:

To check the consistency of pair wise comparison matrix, consistency index (CI) and consistency ratio (CR) are calculated. If someone‟s qualitative judgment is as:

A > B, and B> C, then in case of consistence opinion A>C

Prof. Saaty proved that for consistent reciprocal matrix, the largest Eigen value is equal to the number of variables/attributes, orλ_{max} = n. Then he gave a measure of consistency, called Consistency Index as deviation or degree of consistency using the following formula.

$$CI = (\lambda_{max} - n) / (n-1) \qquad (2.2)$$

For using the consistence index, Prof. Saaty proposed that we use this index by comparing it with the appropriate one. The appropriate Consistency index is called Random Consistency Index (RI). He randomly generated reciprocal matrix using his scale and get the random consistency index to see if it is 10% or less and finally gives a table for RI.

Table 2.1: Random Consistency Index (RI)

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

By using RI, We can calculate Consistency Ratio (CR), which is a comparison between Consistency Index and Random Consistency Index, or in formula

$$CR = CI/RI \tag{2.3}$$

If the value of CR is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, we need to revise the subjective judgment.

2.11.3 Formulation/Steps of AHP

The mathematical formulation of the AHP has been well presented by Saaty in 1978. The AHP provides a means of decomposing the problem into a hierarchy of sub-problems which can more easily be comprehended and subjectively evaluated. The subjective evaluations are converted into numerical values and processed to rank each alternative on a numerical scale. The AHP uses hierarchical decision models and it has a sound mathematical basis. A model is a representation of a phenomenon. It can be manipulated the model, either physically if it is a physical model, or mathematically in the case of hierarchical model, in an attempt to discover the important influences.The methodology of the AHP can be explained in following steps:

Step 1: The problem is decomposed into a hierarchy of goal, criteria, sub-criteria and alternatives. This is the most creative and important part of decision-making. Structuring the decision problem as a hierarchy is fundamental to the process of the AHP. Hierarchy indicates a relationship between elements of one level with those of the level immediately below. This relationship percolates down to the lowest levels of the hierarchy and in this manner every element is connected to every other one, at least in an indirect manner. A hierarchy is a more orderly form of a network. Saaty suggests that a useful way to structure the hierarchy is to work down from the goal as far as one can and then work up from the alternatives until the levels of the two processes are linked in such a way as to make comparisons possible. Figure 2.1 shows a generic hierarchic structure. This local concentration of the decision-maker on only part of the whole problem is a powerful feature of the AHP.

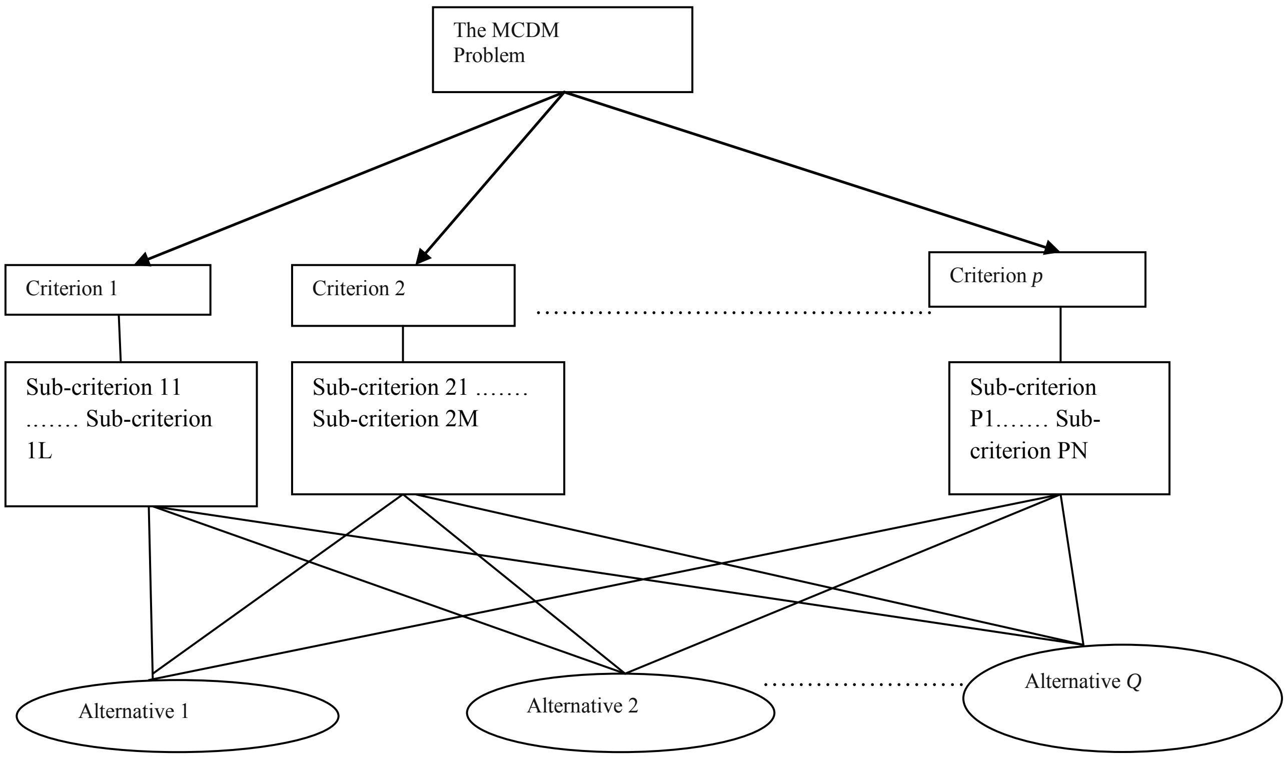


Figure 2.1 Generic hierarchic structure of AHP

Step 2: Data are collected from experts or decision-makers corresponding to the hierarchic structure, in the pairwise comparison of alternatives on a qualitative scale.

Step 3: The pair-wise comparisons of various criteria generated at step 2 are organized into a square matrix. The diagonal elements of the matrix are 1. The criterion in the i_{th} row is better than criterion in the j_{th} column if the value of element (i, j) is more than 1; otherwise the criterion in the j_{th} column is better than that in the i_{th} row. The (j, i) element of the matrix is the reciprocal of the (i, j) element.

Step 4: The principal eigenvalue and the corresponding normalized right eigenvector of the comparison matrix give the relative importance of the various criteria being compared. The elements of the normalized eigenvector are termed weights with respect to the criteria or sub-criteria and ratings with respect to the alternatives.

Step 5: The consistency of the matrix of order n is evaluated.

Step 6: The rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global weight.

Step7: According to the Global weight the ranking of Alternatives can be determined.

2.12 Fuzzy AHP

Fuzzy logic can handle vague information. It has been widely recognized that most decisions made in the real world take place in an environment in which the goals constraints, because of their complexity are not known precisely. These problems cannot be exactly defined. Hence, these situations require precisely represented crisp values [49]. To deal with the kind of qualitative, imprecise information or even ill structured decision problems, fuzzy set theory is suggested by as modeling tool for complex systems that can be controlled by humans but are hard to define exactly. In most of the real world problems, some of the decision data can be precisely assessed while others cannot. The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Despite the convenience of AHP in handling qualitative and quantitative 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 process. So many researchers who have studied Fuzzy AHP have provided the evidence that Fuzzy AHP shows relatively more sufficient description of this kind of decision making [50].

The basic operations of FAHP are not difficult to understand. Instead of assigning deterministic values in the pairwise comparisons process, the judgments are made using linguistic parameters (e.g. more important, very important) which are characterized by fuzzy membership functions. If there is more than one expert involved in the judging process, different matrices are combined together to form one synthetic pairwise comparison matrix. The fuzzy geometric mean approach is the most popular approach to construct the matrix. After that, the matrix needs to be defuzzified (i.e. turn the fuzzy values into crisp values). There are many approaches to handle this process, but the Centre of area approach is the most commonly employed. The remaining procedures are just standard AHP operations.

Fuzzy Extent analysis is first analysis proposed by Chang to help formulate the fuzzy decision-making process, which is multi-tier in nature. Like in FAHP, the fuzzy judgment matrix is first constructed. Then, the synthetic degree value is calculated (instead of defuzzifying the matrix). These values are also fuzzy numbers, and because of this analysis, the method is called extent analysis. Another method which is used for Fuzzy AHP analysis is geometric means method of Buckley gives reliable result [51].

There are several fuzzy AHP methods explained in the literature. Table 2.2 gives a comparisonof these methods, which have important differences in their theoretical structures. The comparison includes the advantages and disadvantages of each method.

Table 2.2: The comparison of different fuzzy AHP methods

Source	The main Characteristic	Advantages (a) and Disadvantages (D)
Van Laarhoven and Pedrycz [50]	-Direct extension of Saaty‟s AHP method with triangular fuzzy numbers - Lootsma‟s logarithmic least square method is used to derive fuzzy weights and fuzzy performance scores	A) The opinions of multiple decision-makers can be modeled in the reciprocal matrix (D) There is not always a solution to the linear equations (D) The computational requirement is tremendous, even for a small problem (D) It allows only triangular fuzzy numbers to be used
Buckley [51]	-Extension of Saaty‟s AHP method With triangular/ trapezoidal fuzzy numbers -Uses the geometric mean method to derive fuzzy weights and performance scores	(A) It is easy to extend to the fuzzy case (A) It guarantees a unique solution to the reciprocal comparison matrix (D) The computational requirement is tremendous
Chang [52]	-Synthetically degree values - Layer simple sequencing -Composite total sequencing	(A) The computational requirement is relatively low (A) It follows the steps of crisp AHP. It does not involve additional operations (D) It allows only triangular fuzzy numbers to be used

In Direct extension of Saaty‟s AHP method with triangular fuzzy numbers each ratio expressing the relative significance of a pair of factors is displayed in a matrix, from which suitable weights can be extracted. Since these ratios are essentially fuzzy-they express the opinion of a decision-maker on the importance of a pair of factors-we have adapted the above-mentioned method in such a way, that decision-makers are asked to express their opinions in fuzzy numbers with triangular membership functions. We apply the method at two distinct levels: first to find fuzzy weights for the decision criteria, and second, to find fuzzy weights for the alternatives under each of the decision criteria. By a suitable combination of these results, we obtain fuzzy scores for the alternatives, as well as their sensitivities. Using these fuzzy scores, the decision-makers should be able to make a choice for one of the alternatives.

In this thesis, we have used Buckley"s geometric mean method to derive fuzzy weights and performance scores as it guarantees a unique solution to the reciprocal comparison matrix.

2.13Brief Focus on Power Situation of Bangladesh

The present installed Power Generation capacity by primary source type of Bangladesh in shown in Fig.2.2 and the power generation capacity by primary sourcetypeis shown in Fig. 2.3.

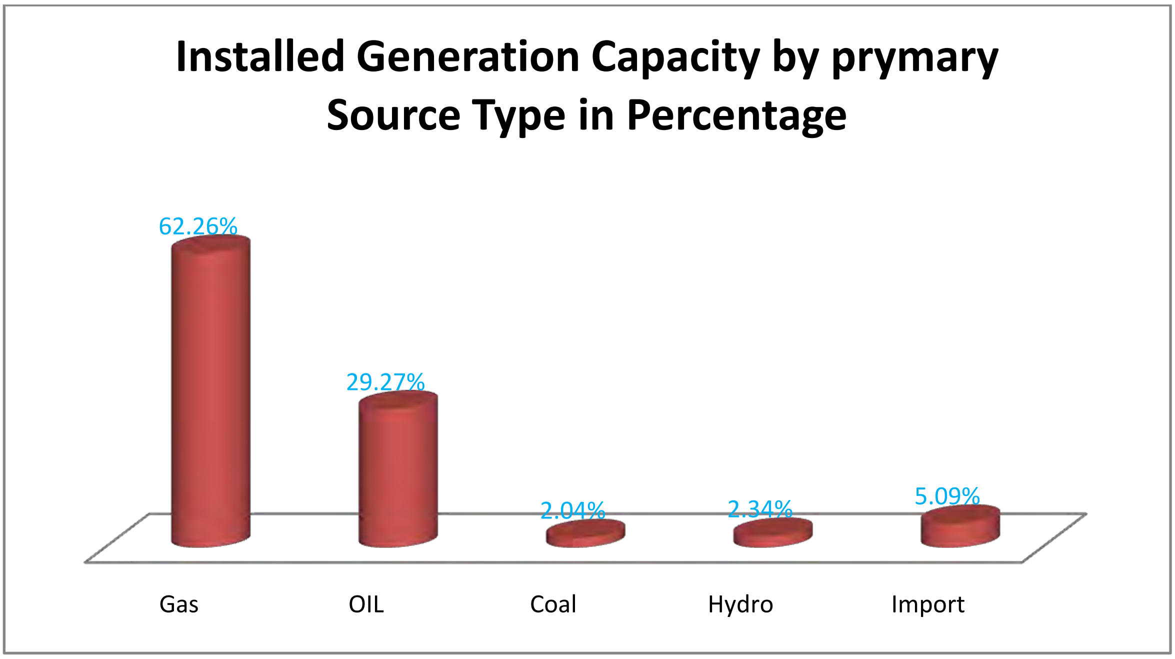


Figure 2.2: Installed Generation Capacity by Primary Source Type (Annual Report BPDB, 2014)

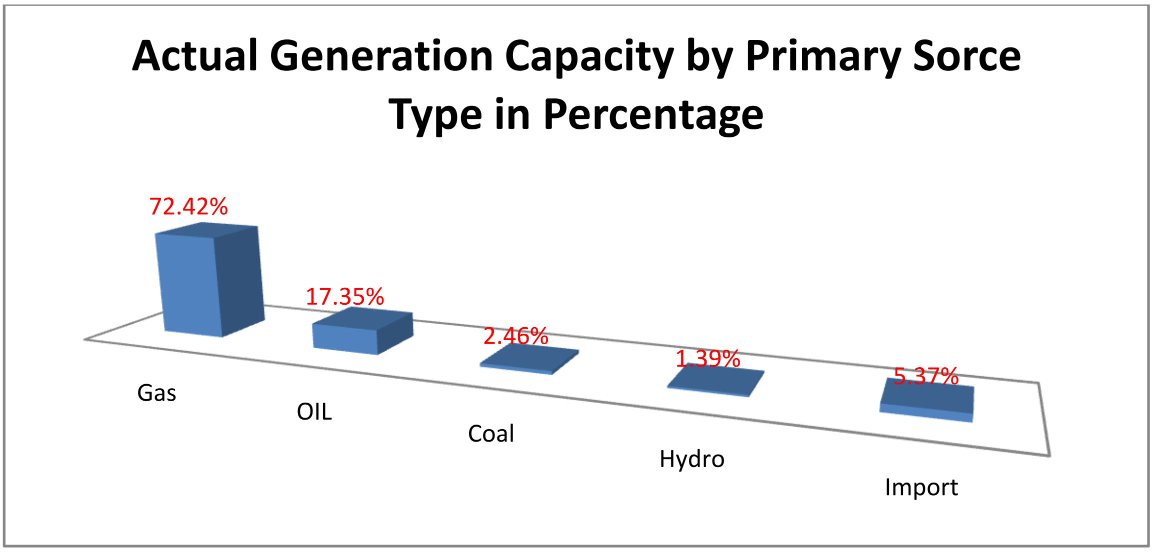


Figure 2.3: Generation by Primary Source Type (Annual Report, BPDB, 2014)

Sector wise Natural Gas Consumption:

Natural gas is the main source of fuel for power, fertilizer, industrial, commercial and domestic sectors of Bangladesh. Present Sector-wise natural gas consumption of Bangladesh is shown in Fig.2.4

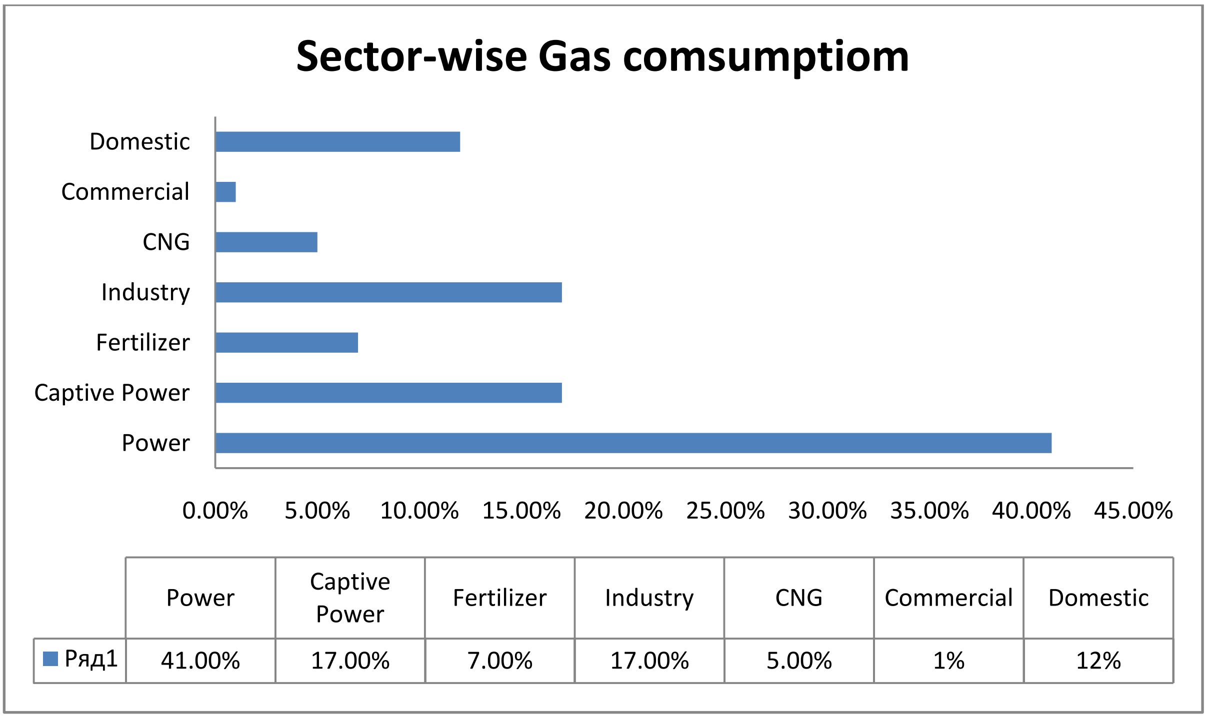


Figure 2.4: Sector wise Gas consumption (AnnualReport,Titas Gas Ltd, 2014)

Natural Gas and Coal Reserves

Natural gas is an important source of energy of Bangladesh that accounts for 72 percent of the commercial energy of the country. Till date 26 gas fields have been discovered in the country. According to the latest estimate total initial gas in place (GIIP) is 37910 Billion cubic feet (BCF), of which 27070 BCF is recoverable in proven and probable categories. As of June 2014, total 12140 BCF gas has been produced leaving 14940 BCF net recoverable. A total of 800.6 BCF gas was produced in FY 2012-13 and 820.3 BCF gas was produced in FY 2013-14. All these are shown in fig 2.5.

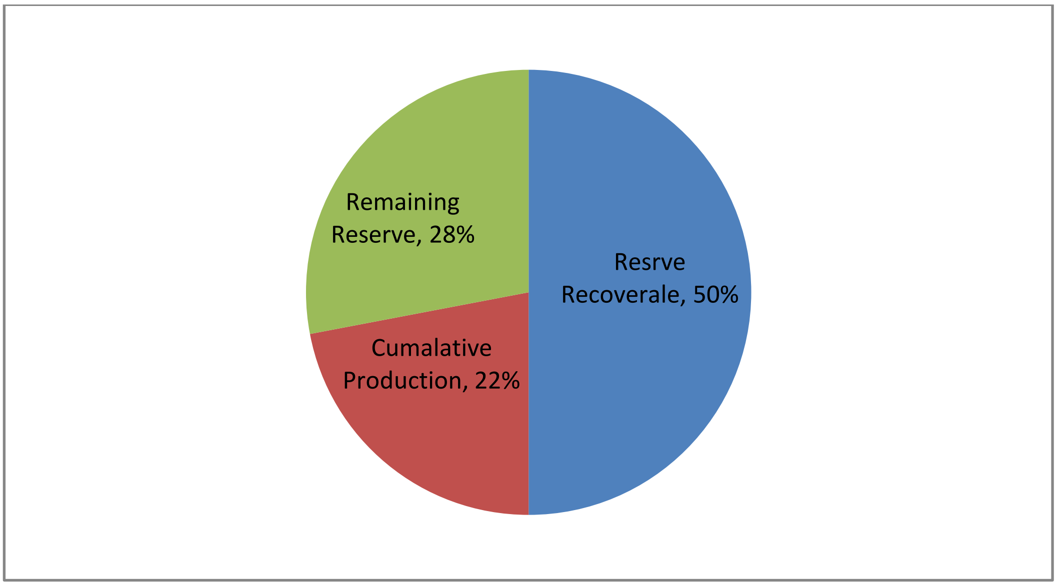


Figure 2.5: Natural gas reserve, cumulative production and remaining reserve (Annual Report, Titas Gas Ltd., 2014)

If the gas uses increased by 5% per year, the proven recoverable natural gas will approximately be finished by 2028.

Coal: There is approximately the reserve of coal is about 3.3 billion tons in Bangladesh [6]. But there is no clear study about what percentage of coal is recoverable and the use of coal is very little whichis5, 40,000 Tons in 2013-14 FY [7, 10].

Future Power Generation Plan

In Bangladesh, indigenous natural gas, coal, LPG, LNG, nuclear, and hydro resources are mainly considered as fuel for the additional power generation plan. It also includes cross-border trade. Other factors such as availability of fuel, cooling water, transportation of heavy equipment, proximately to grid network and load center etc. are also considered for plant placement. The generation plan up to 2030 segmented by primary fuel source type is illustrated by the Power System Master Plan (PSPM 2010) as shown in Fig.2.6.

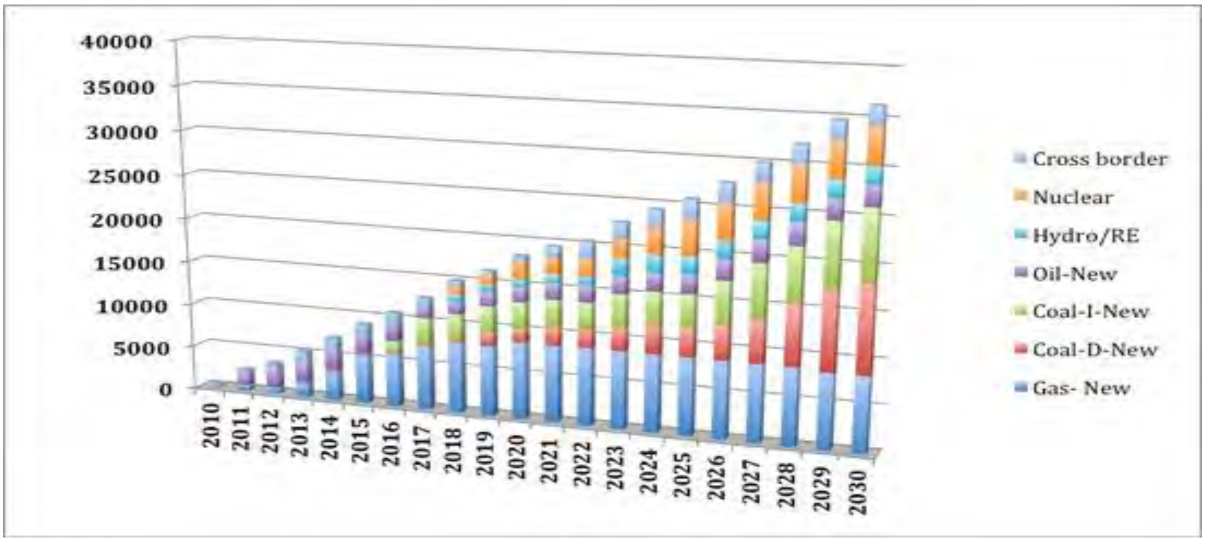
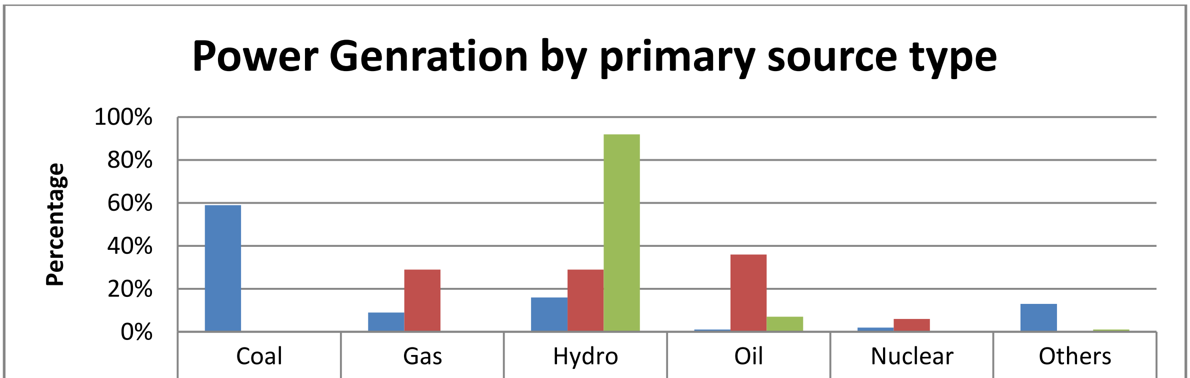


Figure 2.6: Power Generation Plan till 2030 by primary source Type (Report of Power Division, 2014)

2.14 Power Generation Scenario in some SAARC countries and globally

In this thesis we are interested about the primary resource type which is used for power generation. So, in this case, a brief focus is given on some SAARC countries which is shown in Fig.2.7.



	Coal	Gas	Hydro	Oil	Nuclear	Others
India	59%	9%	16%	1%	2%	13%
Pakistan	0%	29%	29%	36%	6%	0%
Srilanka	0%	0%	92%	7%	0%	1%

Figure 2.7: Sector wise power generation in India, Pakistan Sri lanka (eia Report, 2014)

The present Power Generation scenario of primary resource type in the global perspective is shown in Fig.2.8.

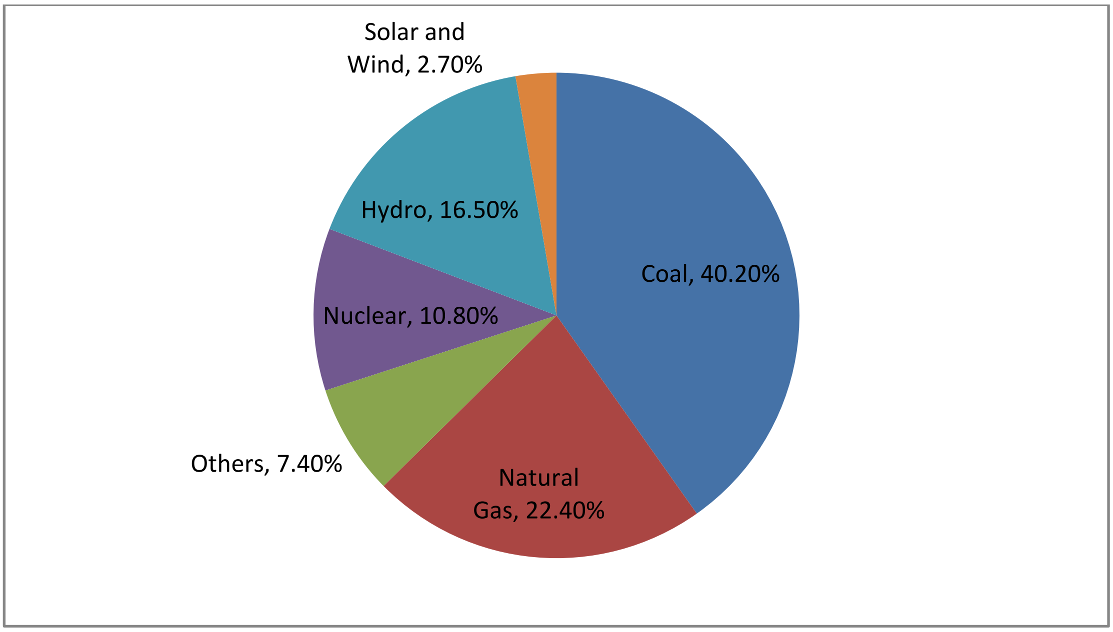


Figure 2.8 Sector wise world electricity generation (eia Report, 2013)

3. METHODOLOGY

3.1 Problem Identification and Problem Structuring

The first phase in the energy-system planning process is to identify the problem. In the start of the planning process, it is common to have a complex and unstructured decision problem. Before the actual planning can start, it is necessary for all stakeholders, DMs and analysts to agree on the exact nature of the problem. It is essential that the problem is thoroughly identified, so that there are no disagreements among the various DMs and the analyst regarding the nature of the problem and the desirable achievements.

Examples of typical questions that should be posed during the problem identification phase based on [53]:

• What is the current situation, and what will be the future development without any action?
• What are the goals to be achieved?
• What opportunities exist now or may develop in the future?
• What threats might create obstacles?

After the problem has been identified, it must be structured in more detail. All essential aspects must be identified and clarified. This information will form the foundation for the later use of MCDM, and the information collected will ensure a common understanding of the situation. A mismatch between the model and the problem is a commonproblem, which in many cases can easily be avoided by spending sufficient time and resources on the problem structuring. There is absolutely no reason to expend a great deal of time and effort on a wonderful analysis of something that later turns out to be the wrong problem. In the problem-structuring phase, it is important to realize that there is always the option to continue with "business as usual", and that option should always be included in the analysis.

3.2 Objectives and Criteria in Energy-Systems Planning

An objective is a statement of something that one wants to achieve, and is characterized by a value criterion and a direction of preference [54]. Identification of objectives is critical for any problem. Keeney lists some desirable properties that can be used as guidelines in deciding which objectives to include in the analysis [55].

• **Complete**: All important consequences of the alternatives can be described in terms of the objectives. It is important that no major categories of performance are overlooked.

• **Non-redundant**: Overlapping concerns should be avoided, and there is no reason to include an objective for which all available alternatives achieve the same or a very similar performance level. For example, it is not necessary to include maximization of income from the project if all alternatives provide the same income. Neither is there any reason to include an objective if the likelihood of there being a differencein the outcome does not justify the inclusion. However, it is important to be careful if removing redundant criteria. Later in the process, new alternatives may be introduced that differ considerably for one of the criteria that have been eliminated.

• **Concise:** The number of objectives should be at the minimum level for a quality analysis. Double-counting should be avoided.

• **Specific:** The consequences of concern should be clear, and it should be possible to select/define attributes for the objectives.

• **Understandable**: The objectives must be specified clearly enough that the DMs are able to understand what is meant by them.

3.3 Decision Alternatives

In energy generation system planning, a common approach is to think in terms of a finite number of possible generation methods alternatives. This is logical considering the limitation in the number of local energy resources, and also the limited number of available technical solutions for conversion, storage and transportation of these energy resources.

Consequently, the expansion problem can be separated in two parts; an operation problem and an investment problem. The operational problem can be seen as a multiobjective decision problem which can be formulated and solved through a number of optimization techniques. The investment problem is a multi-attribute decision problem that can be solved by using various multi-criteria methods. The main challenge is to design a realistic and sound process to assess the DMs‟ preferences regarding the criteria.

In this thesis, the term „alternative‟ has been frequently used to describe the power generation methods that can be chosen. Accordingly, an alternative in an energy-planning project will usually consist of a number of methods that are combined to make possible solutions for meeting the energy demand in the future. It is important that the set of alternatives produces meaningful differences in the type of option and its impacts. During the MCDA process, it is common for new alternatives to be created, or that existing alternatives are modified or removed from the analysis.

3.4Main Uncertainties

In a planning process, it is also necessary to take into account the uncertainty inherent to the planning environment. Uncertainty is a key characteristic of the real world, and energy planning is by its nature an intricate task concerned with complex technological systems interacting in multiple ways. The decomposition of uncertainty is often a subject of research in decision theory. A detailed discussion of risk and uncertainty associated with the decision-making process in energy planning is beyond the scope of this thesis. However, in an MCDA process, it is essential to pay attention to the uncertaintyissue, and decide how, and to what extent, it should be incorporated into the analysis.

It can be distinguished between two general forms of uncertainty; (a) external uncertainty; occurrence of non-controllable events that might have an effect on the decision outcome, and (b) internal uncertainty; uncertainties related to the process of problem structuring and interpretation of the DM‟s preferences [56].

External uncertainties include uncertainties caused by missing information, the stochastic nature of the variables involved and/or the lack of human experience regarding some phenomena. Examples of external uncertainties are the future demand growth, for different types of energy end-uses, future changes in costs and availability ofprimary resources and technologies, the future market prices for different energyetc. When including uncertainties in the input data, it is important to consider possible alternatives from a short- (daily operation), medium- or long-term time frame. Forexample, the uncertainty related to the daily spot price and the short-term demand forecast in the electricity market will strongly influence the profitability of a new local combined heat and power plant. In addition, unpredictable actions by other actors within the energy or financial markets, economic growth, environmental regulation, inflation, Changes in the interest rates and changes in the public opinion should be included among the external uncertainties.

The internal uncertainties can be divided in three groups; (1) uncertainties related to the model structure, (2) uncertainties related to the judge mentalinputs required by the model, and (3) uncertainties related to the DMs‟ understanding of the results fromthe model. The first of these groups includes imprecision or ambiguities in the process of identifying the decision problem, including the definition of alternatives or criteria. Such uncertainties can be reduced if the chosen MCDM process provides the opportunityto step back in the process to restructure the problem or to consider the problem from a different angle. The second group of internal uncertainties is mainly related to the choice of MCDM method and the DMs‟ ability to express their value judgments‟. Although it is generally assumed that the DM is able to express preferences about different decision alternatives, it is not necessarily clear how well he understands the implications of different alternatives and how precisely and consistently he manages to express his preferences for different criteria. For instance, it might be difficult for the DM to decide if something is strongly or very strongly preferred in the AHP method, todetermine the exact value of his indifference between two criteria in the swing weighting method. This last group reflects the possibility that the results from the analysis have been misunderstoodby the DM, or that the results have been interpreted in way other than that allowed by the method.

3.5 Construction of the Algorithm flow Chart

As an MCDM process does not just consist of the multi-criteria evaluation of alternatives. Much of the MCDM literature focuses on the evaluation of well-defined and neatly structured decision problems, where all objectives, alternativesand potential uncertainties are pre specified. However, in practice, it is unlikely that any decision problem will present itself to an analyst in that form. Accordingly, much initial structuring and modeling work is necessary before the actual decision making can start.

There are different steps in a Power Generation energy-planning MCDM process by Fuzzy AHP, as presented in figure 3.1

First of all, it is developed the algorithm flow chart for Fuzzy AHP through the literature review and theoretical and conceptual framework as follows:

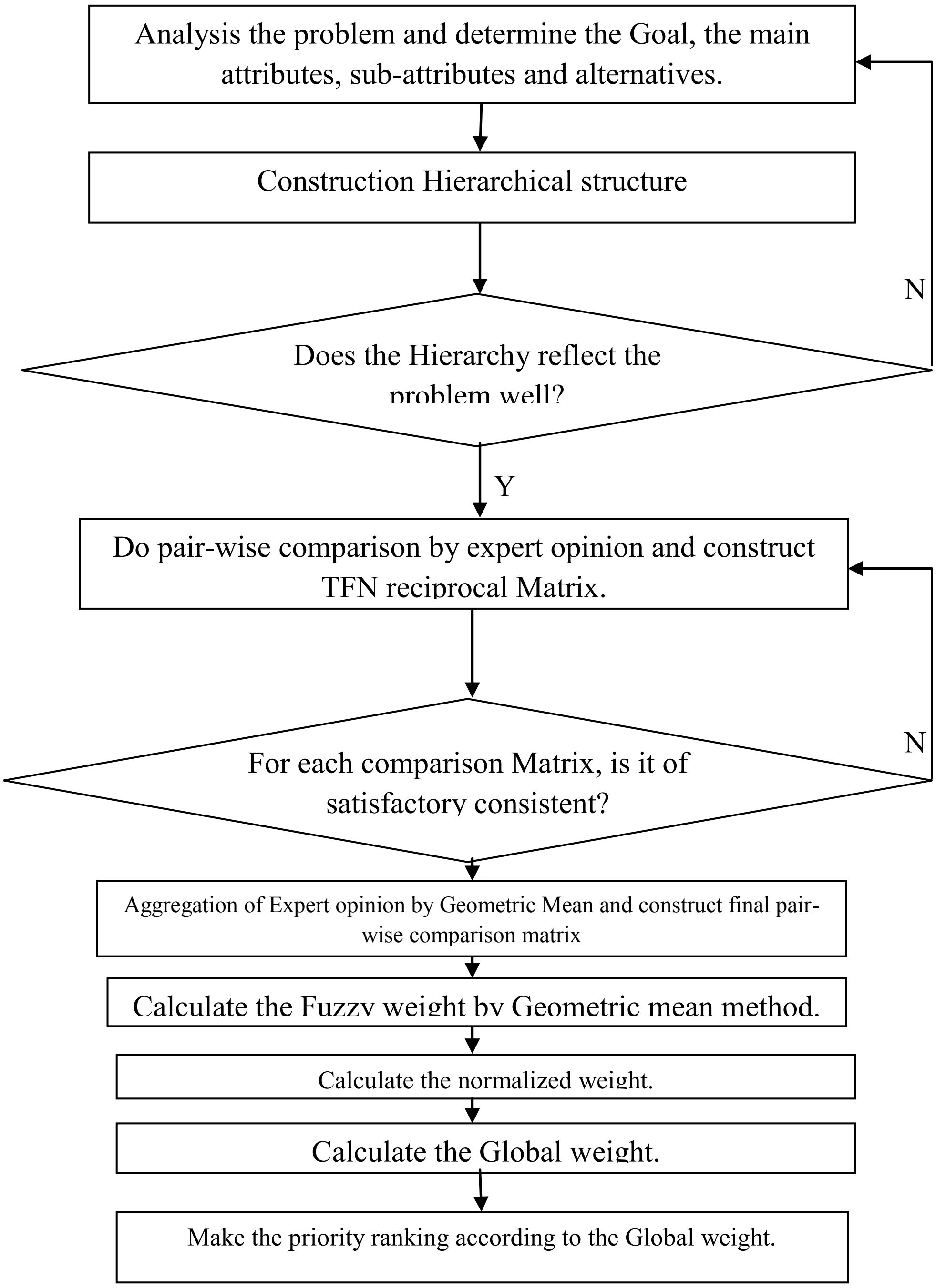


Figure 3.1: Flow chart of Fuzzy AHP

The first step of the Power Generation energy-planning MCDM process is to identify the actual problem and then to form hierarchical structure of the problem in more detail.

Although MCDM above was presented as a process that is conducted step-by-step, MCDM is actually an iterative process. It is not necessary to get everything „perfect" from the start. There will be numerous opportunities during the process to return to an earlier phase, for example to modify an existing alternative, to include an additionalobjective or to make changes in the attributes. It is important to trust the DMs" intuitions and gut feelings in these cases. If any of the DMs claim that the results of the modeling do not feel right, this discrepancy should be explored. The DM"s intuition might be wrong, but it is also possible that revisions of the model are necessaryor advantageous.

3.6 Fuzzy set and fuzzy number

Fuzzy set theory was first presented by Zadeh in 1965 [49]; it emphasizes the fuzziness of humanthinking, reasoning, and cognition of surroundings. A number of conventional quantitative analysismethods cannot analyze such things efficiently. The concept of fuzzy logic must be used to describe actual things and to compensate for the failings of traditional theory sets that use only binary logic to describe things. Fuzzy logic uses the concept of membership function to describe things in a manner similar to common human language. Furthermore, fuzzy logic can analyze ambiguity and vagueness.

The fuzzy set can be defined as follows:

$$\tilde{A} = \{((x, \mu_{\tilde{A}}(x))) \mid x \in U)\} \qquad (3.1)$$

Where, $\tilde{A}$ is a fuzzy set; $\mu_{\tilde{A}}(x)$ is called the membership function. U is the universe of discourse. $\mu_{\tilde{A}}(x)$ ranges between 0 and 1. This is called the degree of membership. The fuzzy set can betterdescribe the characteristics of things compared to conventional binary logic. In conventional crisp sets, the value of the membership function can only be 0 or 1. Equation 3.2 expresses its membership function.

Equations 3.3 to 3. 6 show the rules of operation for the triangular fuzzy number. The defuzzificationoperation should be performed according to the three criteria of rationality, ease of computation, andcontinuity to identify an appropriate point to represent the fuzzy number. Commonly useddefuzzification methods include the mean of maximum method, the center of gravity method, and thecenter of area method [50].

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-c}{a-c}, & c \leq x \leq a \\ \frac{x-b}{a-b}, & a \leq x \leq b \\ 0, & \text{Otherwise} \end{cases} \tag{3.2}$$

Where $a \leq b \leq c$; If $a= b = c$, the Fuzzy number gets a crisp value. Here, a, b, and c are the lowest possible value, the most possible value, and the largest possible value respectively. A TFN is represented as (a,b, c) as illustrated in Fig.3. 2.

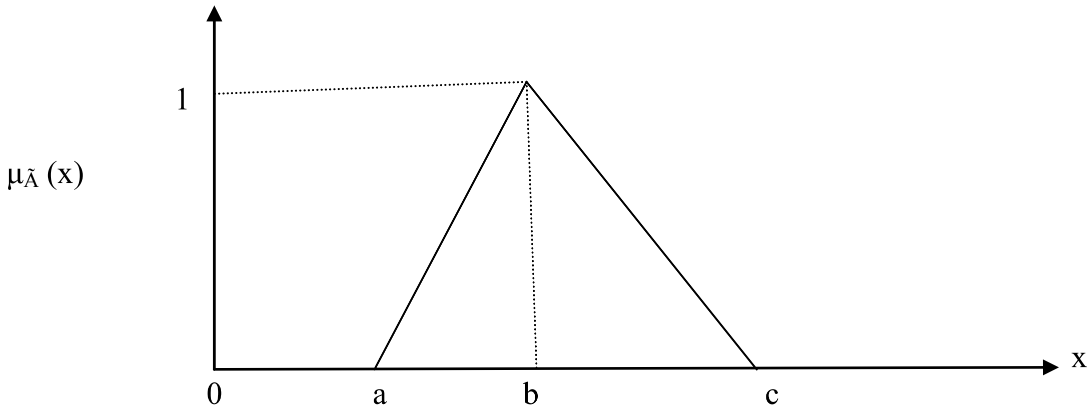


Figure 3.2: Triangular Fuzzy Number

If we define two positive Fuzzy Triangular Numbers, $\tilde{A} = (a_1, b_1, c_1)$ and $\tilde{B} = (a_2, b_2, c_2)$, then the following operations are correct:

$$\tilde{A} \oplus \tilde{B} = (a_1 + a_2, b_1+b_2, c_1+c_2) \tag{3.3}$$

$$\tilde{A} \ominus \tilde{B} = (a_1-a_2, b_1-b_2, c_1-c_2) \tag{3.4}$$

$$\tilde{A} \otimes \tilde{B} \approx (a1 \times a2, b1 \times b2, c1 \times c2)$$

$$\tilde{A} \oslash \tilde{B} = (a_1 \div a_2, b_1 \div b_2, c_1 \div c_2) \tag{3.5}$$

$$\tilde{A}^{-1} \approx (a_1, b_1, c_1)^{-1} \approx (1/a_1, 1/b_1, 1/c_1) \tag{3.6}$$

In this thesis, Fuzzy AHP will be preferred in the prioritization of different power generation methods since this method is the only one using a hierarchical structure among goal, attributes and alternatives. Usage of pair-wise comparisons is another asset of this method that lets the generation of more precise information about the preferences of decisionmakers. Moreover, since the decision-makers are usually unable to explicit about their preferences due to the fuzzy nature of the decision process, this method helps them providing an ability of giving interval judgments instead of point judgments.

3.7 Impact Assessment

For a DM to be able to choose among various power generation methods, he needs to know how the plans being considered will perform against various criteria. Accordingly, one important step in defining and solving the power generation planning problem consists of identifying, structuring and providing guidelines for measuring the achievements in different criteria or attributes.

It is often difficult to decide which impacts are relevant to the analysis, and which can be disregarded. The general solution is to identify all effects that change as a consequence of the decision. Everything that does not change as a consequence of the decision is irrelevant to the analysis and should be disregarded.

3.8 Uncertainties

In MCDM problems, there are two general forms of uncertainty; (a) external uncertainty; occurrence of non-controllable events that might have an effect on the decision outcome, and (b) internal uncertainty; related to the process of problem structuring and interpretation of the DM"s preferences [57, 58].

Our concern in this paper is with the first form of uncertainty. A major problem in decision-making situations is that we are not able to predict the future with certainty. It is difficult, or even impossible, to forecast the future outcome of important decision attributes, such as operating costs and harmful emissions. Even the investment cost of a Project is often estimated incorrectly.

One important decision that has to be made is regarding the types of external uncertainties that should be included in the analysis. Energy generation planners face a range of different uncertainties. Some of the most important are:

Physical: For example, future energy demands, as affected by climatic conditions, technological improvements, and people‟s attitude to energy conservation.

Economic: For example, the variation in future fuel and electricity prices.
Regulatory: Changes in future market and environmental regulations.

Some of the uncertainty factors will influence the decision outcome more than others. Uncertainty factors with low impact should be excluded from the analysis to reduce the amount of work and time involved, and to avoid possible confusion.

Internal uncertainty; uncertainties related to the process of problem structuring and interpretation of the DM‟s preferences. Both external and internal uncertainties can be well handled by the Fuzzy AHP to reduce the error of MCDM problems like the energy generation planning.

3.9 Steps of Fuzzy AHP Calculation

Step1.A hierarchical decomposition structure has been constructed

For constructing the hierarchical decomposition structure, I have used observation and literature review knowledge as well as the Delphi Technique to determine the variables (main attributes, sub-attributes and alternatives).

The Delphi technique, mainly developed by DalkeyandHelmer at the Rand Corporation in the 1950s, is a widely used and accepted method for achieving convergence of opinion concerning real-world knowledge solicited from experts within certain topic areas[59].Predicated on the rationale that, "two heads are better than one, or...n heads are better than one", the Delphi technique is designed as a group communication process that aims at conducting detailed examinations and discussions of a specific issue for the purpose of goal setting, policy investigation, or predicting the occurrence of future events. Commonsurveys try to identify "what is," whereas the Delphi technique attempts to address "what could/should be".

The Delphi technique is a widely used and accepted method for gathering data fromrespondents within their domain of expertise. The technique is designed as a group communication process which aims to achieve a convergence of opinion on a specific real-world issue. The Delphi process has been used in various fields of study such as program planning, needs assessment, policy determination, and resource utilization to develop a full range of alternatives, explore or expose underlying assumptions, as well as correlate judgments on a topic spanning a wide range of disciplines. In this study seven experts were chosen for selecting the attributes, sub attributes and alternatives. The personal profile of Delphi expert panel is shown in table 3.1.

Table 3.1: personal profile of Delphi Expert panel

Number	Gender	Position	Organization	Age (years)	Experience (years)	Academic Degree	Skill in Relevant sector
1	Male	Professor	Private University	>45	Over 20	Ph.d	Very Much
2	Male	Professor	Public University	>44	Over 19	Ph.d	Very Much
3	Male	Associate Professor	Public University	>40	Over 17	Ph.d	Much
4	Male	GM	DPDC	>45	Over 20	Masters	Very Much
5	Male	DGM	DESCO	>45	Over 20	B.Sc. Engg.	Very Much
5	Male	Executive Engr.	PDB	>45	Over 18	B.Sc. Engg.	Much
7	Male	Executive Engr.	PDB	>45	Over 18	B.Sc. Engg	Much

Based on the interviews and interaction of relevant experts, observation and literature review and by using the principles of Delphi Technique, a well-known tool for the following attributes/ criteria, sub attributes/criteria and the alternatives are included for this study:

3.10 Attributes or Variables

It is often difficult to decide which attributes or impacts are relevant to the analysis, and which can be disregarded. The general solution is to identify all effects that change as a consequence of the decision. Everything that does not change as a consequence of the decision is irrelevant to the analysis and should be disregarded. In this thesis it is tried to identify attributes that are most relevant for energy generation planning by Delphi Technique.

3.10.1 Main Attributes and their Sub-attributes

1. Technological Factor (main attributes)

Power Plant life spans, plant Capacity Factor, Plant Capacity, plant efficiency, load factoretc are considered with respect to technological factor.

Plant design & installation complexity (sub-attributes)

Plant design & installation complexity is another important criteria/attribute to consider for energy generation planning model. Comparisons of best practice are generally confined to this area since factors such as plant operating regime, fuel quality and local ambient conditions are largely beyond the control of the plant owner and operator. For plant design the adoption of supercritical (SC) and ultra-supercritical (USC) conditions for new generating plants has to be considered.

Plant operational complication (sub-attribute)

Operational efficiency is the ratio of the total electricity produced by the plant during a period of time compared to the total potential electricity that could have been produced if the plant operated at 100 percent in the period. Plant maintenance: the actual performance of a plant compared to its design and "as-commissioned" performance is crucial. As equipment wears, fouls, corrodes, distorts and leaks, as sensors and instrumentation fail, and as calibrations drift, the plant tends to become less efficient. As well as ensuring integrity, a key requirement of plant maintenance is to maintain peak efficiency. Improved maintenance and component replacement and upgrading can reduce energy losses.

2. Economic Factor (main attributes)

Economy is an important aspect of all energy-planning problems. An investment will generally not be made if it offers no economic advantages. In most cases, the economic objective is to maximize the value or advantage, or to minimize the total cost associated with an investment.

Initial capital & royalty Cost (sub-attributes)

Initial cost refers to how much does it cost to build different type of power plants and the royalty cost refers to the cost if it has to pay in each year for the technology.

Generation Cost/unit (sub-attributes)

In electrical power generation, the distinct ways of generating electricity incur significantly different costs. Calculations of these costs at the point of connection to a load or to the electricity grid can be made. The cost is typically given per kilowatt-hour or megawatt-hour. It includes the initial capital, as well as the costs of continuousoperation, fuel and maintenance. This type of calculation assists policy makers, researchers and others to guide discussions and decision making.

3. Resource Factor (main attributes)

Electricity is a secondary source of energy that means electricity is obtained from the conversion of other primary sources of energy such as coal, Gas, nuclear, oil, hydro etc. So, for power generation planning the available primary sources must have to be considered for proper planning. Proper human resource is also important in this regard.

Availability of raw Input resource (sub-attributes)

In most power generation methods in the world burn fossil fuelssuch as coal,oil, and natural gas to generate electricity. Others use nuclear power, but there is an increasing use of cleaner renewable sourcessuch as solar, wind, wave and hydroelectric.

Availability of skilled Manpower (sub-attributes)

Only to increase power generation is not sufficient to maintain sustainable power demand meet up. To operate the plant it is necessary to have the trained skilled manpower to maintain the power plants.

4. Environmental Factor (main attributes)

Most energy generation and distribution technologies have some kind of negative environmental impacts. Minimization of the environmental impacts associated with different power generation methods, is therefore often included as objectives in energy generation planning. Different kinds of energy projects have different impacts on the environment. This typically includes factors such as emissions, noise, and aesthetic impact. Ideally, all impacts during the entire life cycle (construction, operation and disposal) of the various power generation methods should be included in the analysis. It can be useful to distinguish between Environmental effects in the construction phase, the normal operation phase and accidental emissions.

Impact on Physical Environment: Land, Air, Water (sub-attributes)

The geographic location of different technological solutions and the boundary of the system being analyzed are important in an environmental analysis. The energy market is international, and decisions about which energy solution to use within the system boundary will often lead to emissions either inside or outside of the system boundary, or even both. Emissions outside of the system boundary are particularly difficult toaddress. According to this study the main objective in l energy generation planning problems is to maximize the well-being of society. However, it is not obvious how “society” should be defined. One alternative is to consider only emissions that occur locally (inside the system boundary). Another alternative is to include also emissions associated with the generation of imported energy carriers. Various impacts on land, air, water also has to be considered.

Impact on Life: Safety & Health (sub-attributes)

Minimization of other environmental impacts, such as noise and negative aesthetic effects, air quality and accidental occurrence can also be included as objectives in the energy generation planning analysis of this study.

5.Population Factor (main attributes)

The total population of Bangladesh is about 160 million with a limited land area of 1 lac 56 thousand square kilometer .Bangladesh has the highest population density in the world, excluding a handful of city states and small countries with populations under 10m, such as Malta and Hong Kong. So, in future power generation planning this truth has to given high preference and we have done it in this study for reliable and sustainable result.

Population Density (sub-attributes)

Bangladesh has the highest population density in the world, excluding a handful of city states and small countries with populations under 10m, such as Malta and Hong Kong.

So, in future power generation planning this truth has to give high preference and we have done it in this study for reliable and sustainable result.

Appropriate Location for Plant (sub-attributes)

Bangladesh is almost a country of plain land and rivers. Almost in every place people are living with high density. So, to install power generation plant the location is very important which has given preference in this study.

3.10.2 Alternatives

In energy generation system planning, a common approach is to think in terms of a finite number of possible generation methods alternatives. This is logical considering the limitation in the number of local energy resources, and also the limited number of available technical solutions for conversion, storage and transportation of these energy resources.

Consequently, the expansion problem can be separated in two parts; an operation problem and an investment problem. The operational problem can be seen as a multi objective decision problem which can be formulated and solved through a number of optimization techniques. The investment problem is a multi-attribute decision problem that can be solved by using various multi-criteria methods. The main challenge is to design a realistic and sound process to assess the DMs‟ preferences regarding the criteria.

In this thesis, the term „alternative‟ has been frequently used to describe the power generation methods that can be chosen. Accordingly, an alternative in an energy-planning project will usually consist of a number of methods that are combined to make possible solutions for meeting the energy demand in the future in Bangladesh perspectives. The alternatives which are considered for the ranking are discussed below:

Gas fired Power Generation Method/Gas fired Power Plant (GFPP):

Electricity is a secondary source of energy that means electricity is obtained from the conversion of other primary sources of energy. If the primary source is Gas, then it is considered as Gas fired power generation method.

Coal Fired Power Generation method/Coal fired Power Plant (CFPP):

Electricity is a secondary source of energy that means electricity is obtained from the conversion of other primary sources of energy. If the primary source is coal, then it is considered as Coal fired power generation method.

Oil fired Power Generation Method/Oil fired Power Plant (OFPP):

Electricity is a secondary source of energy that means electricity is obtained from the conversion of other primary sources of energy. If the primary source is Oil, then it is considered as Oil fired power generation method.

Nuclear Power Generation Method/Nuclear Power Plant (NPP):

Electricity is a secondary source of energy that means electricity is obtained from the conversion of other primary sources of energy. If the primary source is nuclear material, then it is considered as Nuclear power generation method

Hydro Power Generation Method/Hydro Power Plant (HPP):

Electricity is a secondary source of energy that means electricity is obtained from the conversion of other primary sources of energy. If the primary source is hydro, then it is considered as Hydro power generation method.

According to this attributes, sub attributes and alternatives the Fuzzy hierarchical structure is constructed as shown in fig. 3.2

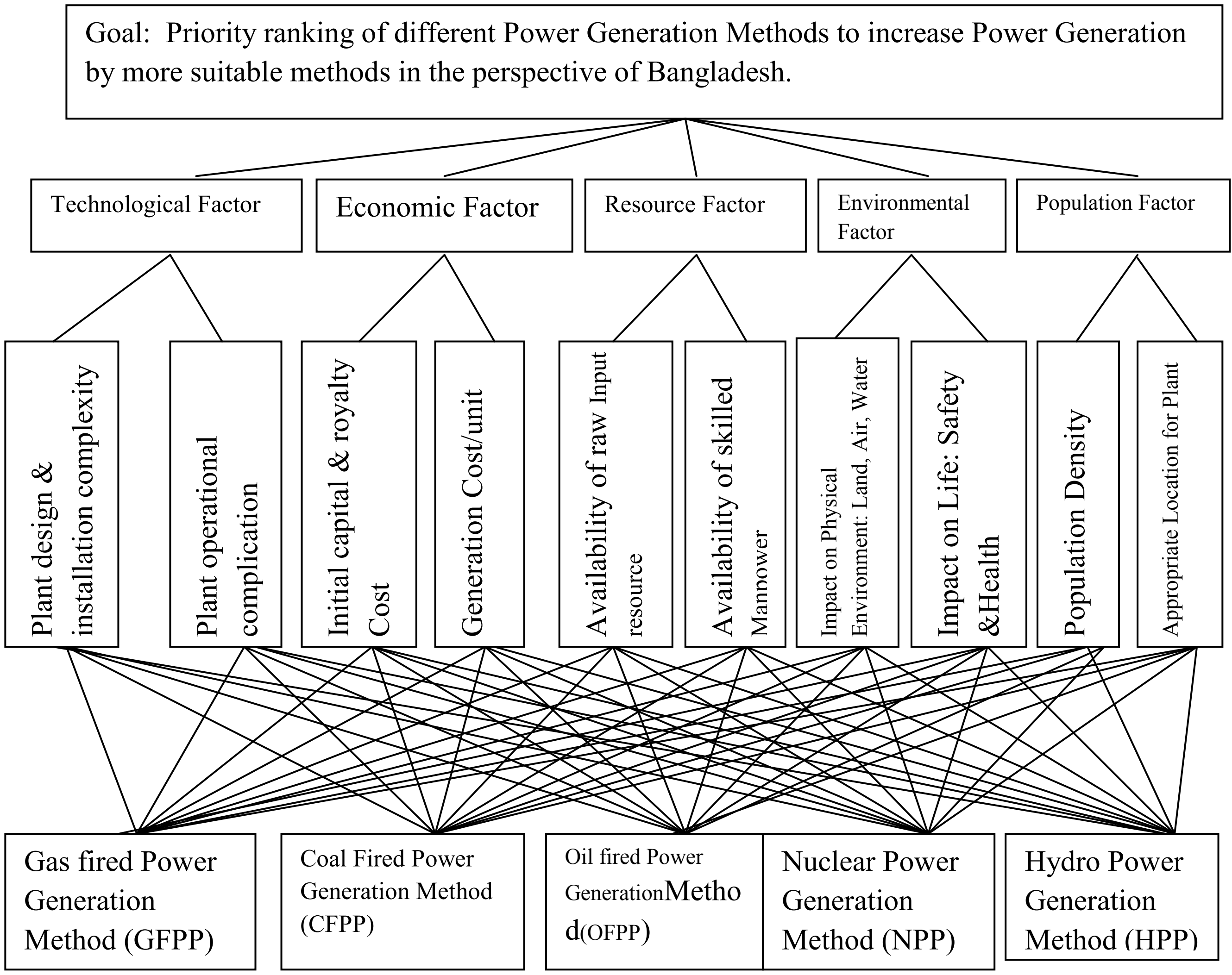


Figure 3.3 Hierarchical decomposition of criteria, sub criteria and alternatives

Step2.The questionnaire isdesigned: Based on the established hierarchical structure, a questionnaire is designed so that compares indicators/attributes to obtain respondents" pair wise opinions with respect to the higher level attributes to form the pair wise comparison matrix. The following TFN conversion scale is used for converting the judgmental opinion of the experts, as shown in Table 3.2.

Table 3.2: Triangular Scale for Triangular Fuzzy number (TFN) conversion

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale

Just equal	(1, 1, 1)	(1, 1, 1)
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Source :(Büyüközkan et al. , 2004)

The sample of the structured questionnaire is given bellow:

Please read the following questions and put check marks on the pair wise comparison matrices.

► If the attribute of „LHS‟ is more important/preferable than the right hand side (RHS) attribute with respect to the element on which it is compared , then use proper scale of left hand side (LHS).

► If the attribute of „RHS‟ is more important/preferable than the Left hand side (RHS) attribute with respect to the element on which it is compared, then use proper scale of right hand side (RHS).

A. With respect to overall Goal "Priority Ranking of Power Generation Methods (Coal, Gas, Oil, Nuclear, Hydro) to increase Power Generation Capacity by more suitable Methods in the Perspective of Bangladesh to meet the present and future demand",

Q1. How important/preferable is Technological Factor (TF) when it is compared with Economic Factor (EF)?

Q2. How important/preferable is Technological Factor (TF) when it is compared with Resource Factor (RF)?

Sample of Questionnaire

With respect to overall Goal.*		Importance (or Preference) of one main –attributes over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
than attributes of RHS								than attributes of LHS					
Q1	TF												EF
Q2	TF												RF

Q3	TF												ENVF
Q4	TF												POPUF
Q5	EF												RF
Q6	EF												ENVF
Q7	EF												POPUF
Q8	RF												ENVF
Q9	RF												POPUF
Q10	ENVF												POPUF

* Goal: Priority ranking of different Power Generation Methods to increase Power Generation by more suitable methods in the perspective of Bangladesh.

B. With respect to main attribute "Resource Factor (RF)",

Q1. How important/preferable is Availability of raw Input Resource (AIR) when it is compared with Availability of Skilled Manpower (SMP)?

Sample of Questionnaire

With respect to Resource Factor (RF)		Importance (or Preference) of one sub –attributes over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	AIR												SMP

C. With respect to sub attribute "Impact on Life (IL): Safety & Health",

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Sample of Questionnaire

With respect to Impact on Life (IL): Safety & Health		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
than attributes of RHS								than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

Full questionnaire is given in the Appendix A.

AIR	Availability of Input Resources	APLOC	Appropriate Plant Location
GC	Generation Cost	IL	Impact on Life
IPENV	Impact on Physical Environment	PDI	Plant Design and Installation Complexity
POC	Plant Operational Complexity	POPDEN	Population Density
SMP	Skilled Man Power	ENVF	Environmental Factor
EF	Economic Factor	POPUF	Population Factor
RF	Resource Factor	TF	Technological Factor
CFPP	Coal Fired Power Plant	GFPP	Gas Fired Power Plant
HPP	Hydro Power Generation Plant	NPP	Nuclear Power Plant
OFPP	Oil Fired Power Plant	ICR	Initial Cost and Royalty

Step 3: The pair wise comparison matrices are formed as follows:

$$A= [\tilde{a}_{ij}] \tag{3.7}$$

Where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$, l_{ij}, m_{ij}, u_{ij} are the lower limit, peak, and upper limit of the triangular fuzzy number, $\tilde{a}_{ij} = 1/ \tilde{a}_{ji}$, where, i, j = 1,2, … , n.

Step 4: The consistency of the pair-wise comparison matrix of each respondent has been checked by the equation 3.3, if consistent, and then preceded to the step 5; otherwise the corresponding respondent"s opinion has been revised.

Step5:It has been used geometric mean operations (Davis, 1994, 52) to aggregate the opinions of respondents in this research.

$$\tilde{A}_{ij} = (\tilde{a}^1_{ij} \otimes \tilde{a}^2_{ij} \otimes \tilde{a}^3_{ij} \otimes \ldots\ldots\ldots\ldots \otimes \tilde{a}^n_{ij})^{1/n} \tag{3.8}$$

Where $\tilde{a}_{ij}$ is the triangular fuzzy number in the ith column and jth row of the fuzzy positivereciprocal matrix and $\tilde{a}^n_{ij}$ is the assessment value of respondent n .

Step 6: Then we have calculated the fuzzy weight by Column geometric mean method.

$$\tilde{w}_i = r_i \otimes (r_1 \oplus r_2 \oplus r_3 \oplus \ldots\ldots\ldots\ldots \oplus r_n)^{-1} \tag{3.9}$$

$$\tilde{r}_i = (\tilde{a}_{i1} \times \tilde{a}_{i2} \times \tilde{a}_{i3} \times \ldots\ldots\ldots\ldots \times a_{in})^{1/n} \tag{3.10}$$

where $\tilde{w}_i$ is the fuzzy weight value of each column in the fuzzy positive reciprocal matrix and $\tilde{r}_i$ is the geometric mean of the triangular fuzzy number.

Step 7.Defuzzification:The fuzzy number has to be defuzzified. We have used a simple centroid method for this purpose Chang and Wang, name the non-fuzzy weights as the "best nonfuzzy performance (BNP) values" asfollows [52]:

$$w_i = a_i+b_i+c_i/3 \tag{3.11}$$

Step 8: Then we haveperformed normalization (Eq. 3.12) to obtain the weights for each aspect and indicator.

$$W_i = W_i / \Sigma W_i \qquad (3.12)$$

Step 9: Then we have performed hierarchical tandem to calculate the global weights of all indicators.

Step 10: Then we have performed priority ranking of alternatives according to the global weight.

3.11Expert Opinion

To build the pair-wise comparison matrices for the main attributes, sub-attributes and alternatives, opinion of some academic experts and professional experts of the relevant field are collected by purposive Sampling method. The purposive sampling method is one on which the sample is selected on need basis according to the specialization [60]. The distribution of the purposive sample was as follows:

Academic Expert	Professional Expert	Total
5 (five)	5 (five)	10 (ten)

3.11.1 Experts‟ personal profile

For eliciting the experts‟ judgmental opinion,5 (Five) academician and 5 professional experts were selected. The personal profile of the experts was shown in table 3.3 and table 3.3.

Academician:

Table 3.3 Personal profile of Academic Expert

Number	Gender	Position	Organization	Age (years)	Experience (years)	Academic Degree	Skill in Relevant sector
1	Male	Professor	Private University	>45	Over 20	Ph.d	VeryMuch
2	Male	Professor	Public University	>44	Over 19	Ph.d	Very Much
3	Male	Associate Professor	Public University	>40	Over 17	Ph.d	Much
4	Male	Assistant Professor	Private University	>37	Over 15	Ph.d	Normal

5	Male	Assistant Professor	Private University	>45	Over 20	Maters	Much

Professional:

Table 3.4 Personal profile of Professional Expert

Number	Gender	Position	Organization	Age (years)	Experience (years)	Academic Degree	Skill in Relevant sector
1	Male	GM	DPDC	>45	Over 20	Masters	Very Much
2	Male	DGM	DESCO	>45	Over 20	B.Sc. Engg.	Very Much
3	Male	Executive Engr.	PDB	>45	Over 18	B.Sc. Engg.	Much
4	Male	Executive Engr.	PDB	>45	Over 18	B.Sc. Engg	Much
5	Male	Executive Engr.	PDB	>45	Over 18	B.Sc. Engg	Much

3.12 Description of online AHP Calculation software by CGI

This online software is used to check the consistency of the pairwise comparison matrix. This software (web system) calculates the weights and CI values of AHP models from Pairwise Comparison Matrixes using CGI systems [61]:

1. Input: Size of Pairwise Comparison Matrix
2. Input: Pairwise Comparison Matrix (The values of Pairwise Comparison)
3. Display: Weights (Eigen Vector) and CI (Eigen Value)
4. Output: Text File. You can use the output by spreadsheets using cut-and-paste.

Please input the size of Pairwise Comparison Matrix (the number of evaluation items or evaluation objects), n where $2 \leq n \leq 9$.

If it is used only normal Comparison Values, that is, 1, 2... 9 and 1/2,1/3,...,1/9, then Check the "ONLY INTEGR VALUES"

Size of Pairwise Comparison Matrix (n) :

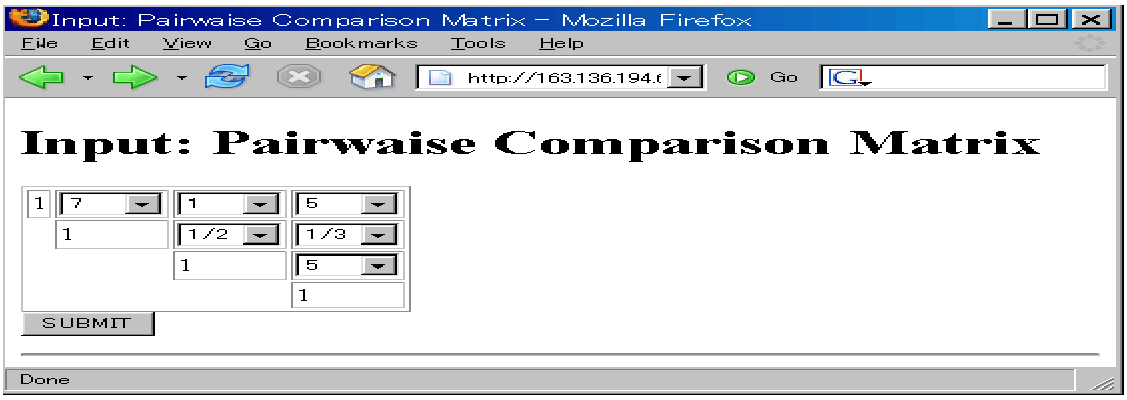
☑ ONLY INTEGR VALUES

Calculation (Software): Weights of AHP (Analytic Hierarchy Process)

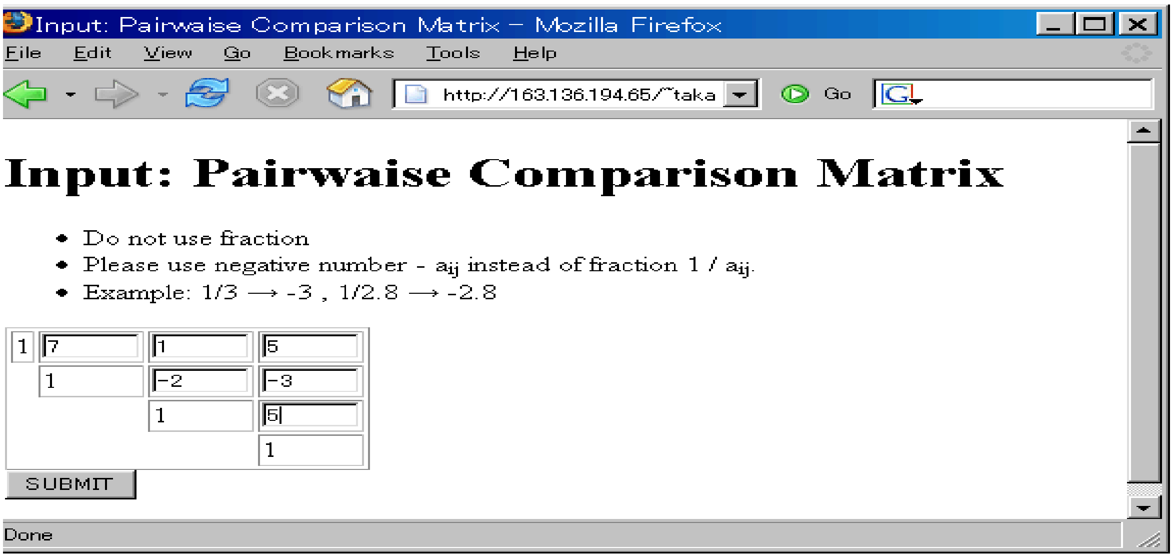
Function

Inputs	• Size of Pairwise Comparison Matrix • Pairwise Comparison Matrix
Outputs	• Weights (Maximum Eigen Vector) • C.I. (Consistency Index) and Eigen Value • Pairwise Comparison Matrix • Text file of above values (To use other software such as spreadsheets)

Input: Pair wise Comparison Matrix (Only Integer Values)



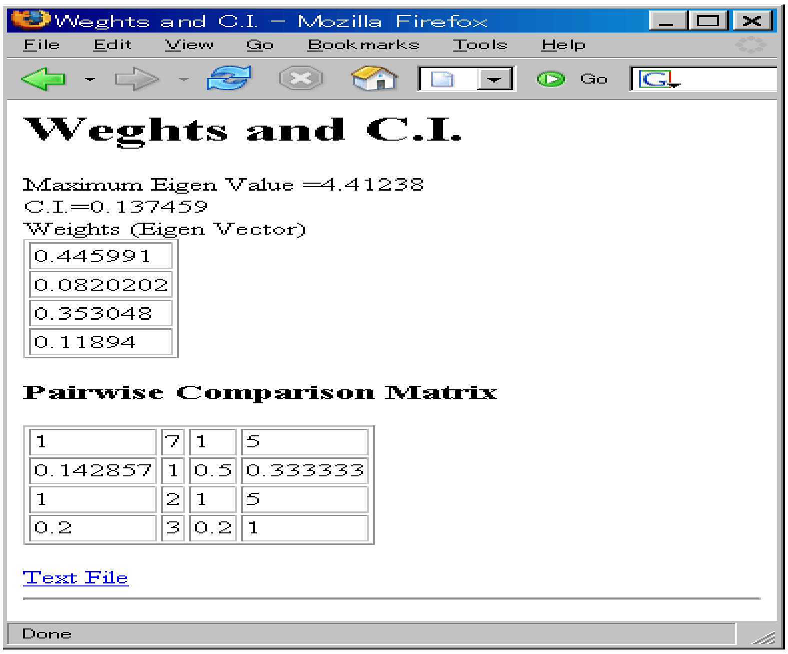
Input: Pair wise Comparison Matrix



Input the Pairwise Comparison Matrix

- Do not use fractions
- You can use negative number $-a_{ij}$ instead of fraction $1 / a_{ij}$
- Example: 1/3 → -3, 1/2.8 → -2.8
-

Output



- C.I. (Consistency Index): If the value is greater than 0.1 or 0.15, we recommend you to retry the Pairwise Comparison.
- Weight (Eigen Vector): Weights of Evaluation Items or Individual Scores of Alternatives
- Pair wise Comparison Matrix

4. DATA PRESENTATION AND ANALYSIS

4.1 Introduction

In this section of this thesis, rigorous mathematical calculation of the pair-wise comparison matrices has been performed. To calculate the global weight of different alternatives, we have used the CGI AHP software and Excel for the mathematical operation of matrices.

4.2 Result Calculation

The data analysis has been made using Microsoft Excel spread sheet and CGI online AHP software. The matrices have diagonal of unity. The lower triangles were made just reversing the corresponding component using equation 3.3. The pair wise comparison matrices are developed by expert opinion. The detailed calculation is shown bellow.

4.2.1Fuzzy AHP calculation for main attributes

We will need these operation laws in order to be able to estimate priorities out of the fuzzy matrix .Before that, we need to assure two points: (I) It is required to evaluate consistency for each respondent, and (II) It is required to find ways of aggregating the single pair-wise comparisons (group decision).

To assure a certain quality level of a decision, to increase reliability and credibility we have to analyze the consistency of an evaluation. For this purpose, we calculated the consistency ratio (CR) confirming Saaty [23], which is defined as a ratio between the consistency of a given evaluation matrix (consistency index CI) and the consistency of arandom matrix (RC).

To simplify the calculation of the Consistency Ratio (CR), we used the crisp value m_{ij}. If the CR is within the tolerable level, we continue the pairwise comparison matrix forfurther analysis. The CR of acceptable level is as follows:

CR $\leq$ 0.1, Acceptable
CR $\geq$0.1,not acceptable

The matrix of pair-wise comparisons depicts the intensities of expert‟s preference/importance between the individual pair with respect to objective. The sample of two matrices with respect to the goal (Goal: Increase Power Generation Capacity to meet present and future demand by more suitable Methods) are given here:

Expert 1: Academician

Table 4.1: Pair wise comparison matrix of main attributes WRT Goal

	TF			EF			RF			ENVF			POPUF		
TF	1.00	1.00	1.00	0.40	0.50	0.67	0.29	0.33	0.50	0.40	0.50	0.67	0.40	0.50	0.67
EF	1.50	2.00	2.50	1.00	1.00	1.00	0.50	0.67	1.00	1.00	1.50	2.00	0.50	0.67	1.00
RF	2.00	3.00	3.51	1.00	1.50	2.00	1.00	1.00	1.00	2.00	2.50	3.00	1.50	2.00	2.50
ENVF	1.50	2.00	2.50	0.50	0.67	1.00	0.33	0.40	0.50	1.00	1.00	1.00	0.50	0.67	1.00
POPUF	1.50	2.00	2.50	1.00	1.50	2.00	0.40	0.50	0.67	1.00	1.50	2.00	1.00	1.00	1.00

By using the CGI software we get the following result (use m_{ij}):

Weights and C.I.
Maximum Eigen Value =5.06038
C.I.=0.0150955
Weights (Eigen Vector)
0.096874
0.195052
0.342458
0.149191
0.216426

CR	0.01028<0.1

The matrix is consistent.

Expert 1: Professional

Table 4.2: Pair wise comparison matrix of main attributes WRT Goal

	TF			EF			RF			ENVF			POPUF		
TF	1.00	1.00	1.00	0.40	0.50	0.67	0.29	0.33	0.50	0.40	0.50	0.67	0.40	0.50	0.67
EF	1.50	2.00	2.50	1.00	1.00	1.00	0.50	0.67	1.00	1.50	2.00	2.50	0.50	0.67	1.00
RF	2.00	3.00	3.51	0.67	1.50	2.00	1.00	1.00	1.00	2.00	2.50	3.00	1.50	2.00	2.50
ENVF	1.50	2.00	2.50	0.50	0.40	0.50	0.33	0.40	0.50	1.00	1.00	1.00	0.50	0.67	1.00
POPUF	1.50	2.00	2.50	1.00	1.50	2.00	0.40	0.50	0.67	1.00	1.50	2.00	1.00	1.00	1.00

Weights and C.I.
Maximum Eigen Value =5.08692
C.I.=0.0217312
Weights (Eigen Vector)
0.096434
0.207274
0.33921
0.141149
0.215934

CR	0.01940<0.1

The matrix is consistent.

4.2.2Aggregation of expert opinion of main attributes

Geometric mean operations are commonly used within the application of the AHP for aggregating groupdecisions [46]. We used the geometric means method to integrate the opinions of respondents in this research using equation (3.8) using Excel Spread Sheet.

$$\tilde{a}_{11}=(\tilde{a}^{1}_{11}\otimes\tilde{a}^{2}_{11}\otimes\tilde{a}^{3}_{11}\otimes \ldots\ldots\ldots\ldots\ldots\ldots \otimes \tilde{a}^{10}_{11})^{1/10}$$

$$= ((1*1*1*1*1*1*1*1*1*1)^{1/10}, (1*1*1*1*1*1*1*1*1*1)^{1/10}, (1*1*1*1*1*1*1*1*1*1)^{1/10})$$

$\tilde{a}_{11}= (1,1,1)$

Similarly, it can be calculated

$\tilde{a}_{12}= (0.384,0.472,0.636)$

$\tilde{a}_{13}=(0.273,0.328,0.481)$

$\tilde{a}_{14} = (0.387, 0.481, 0.641)$

$\tilde{a}_{15} = (0.388, 0.481, 0.639)$

$\tilde{a}_{21}$, $\tilde{a}_{22}$, $\tilde{a}_{23}$, $\tilde{a}_{24}$, $\tilde{a}_{25}$, ------------- , $\tilde{a}_{55}$.

So, the aggregated pair-wise comparison matrix for the main attributes is shown in table 4.3.

Table 4.3: Aggregated Pair wise comparison matrix of main attributes WRT Goal

	TF			EF			RF			ENVF			POPUF		
TF	1.000	1.000	1.000	0.384	0.472	0.636	0.273	0.328	0.481	0.387	0.481	0.641	0.388	0.481	0.639
EF	1.572	2.119	2.608	1.000	1.000	1.000	0.473	0.648	0.967	0.964	1.473	1.972	0.482	0.633	0.975
RF	2.079	3.049	3.663	1.034	1.543	2.114	1.000	1.000	1.000	1.986	2.482	2.979	1.478	1.979	2.477
ENVF	1.560	2.079	2.584	0.507	0.679	1.037	0.336	0.403	0.504	1.000	1.000	1.000	0.485	0.649	0.984
POPUF	1.565	2.079	2.577	1.026	1.580	2.075	0.404	0.505	0.677	1.016	1.541	2.062	1.000	1.000	1.000

Now, it is calculated the priorities via the geometric means method of Buckley [51], which delivers satisfying fuzzy group weightings by using equation (3.10) for the main attributes. The samplecalculation is as follows:

$$\tilde{r}_1=(\tilde{a}_{11}\times\tilde{a}_{12}\times\tilde{a}_{13}\times\tilde{a}_{14}\times\tilde{a}_{15})^{1/5},(\tilde{a}_{21}\times\tilde{a}_{22}\times\tilde{a}_{23}\times\tilde{a}_{24}\times\tilde{a}_{25})^{1/5},(\tilde{a}_{31}\times\tilde{a}_{32}\times\tilde{a}_{33}\times\tilde{a}_{34}\times\tilde{a}_{35})^{1/5}$$

$$=((1*.384*.273*.387*.388)^{1/5},(1*.472*.328*.481*.481)^{1/5},(1*.636*.481*.641*.639)^{1/5}$$

By Excel we can find out the weight $\tilde{r}_1$

$\tilde{r}_1$	0.435807
	0.513832
	0.660073

Similarly it can be obtained the remaining $\tilde{r}_i$, That is:

$\tilde{r}_2$	0.808548
	1.050625
	1.371243

$\tilde{r}_3$	1.445494
	1.873958
	2.245921

$\tilde{r}_4$	0.663714
	0.819255
	1.05839

	0.919845
	1.206569
$\tilde{r}_5$	1.494655

The Fuzzy weight of each attributes of main criteria can be calculated by equation (3.9) by Excel as follows:

$\tilde{w}_1 = \tilde{r}_1 \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \tilde{r}_3 \oplus \tilde{r}_4 \oplus \tilde{r}_5)^{-1}$

$\tilde{w}_1 = (0.435807, 0.513832, 0.660073) \otimes (4.27717, 5.468173, 6.819836)^{-1}$

= (0.435807/6.830283, 0.5138320/5.464239, 0.660073/4.273409)

	0.0638051
	0.0940354
$\tilde{w}_1$	0.1544606

Similarly it can be obtained the remaining $\tilde{w}_i$, that is:

	0.1183769
	0.192273
$\tilde{w}_2$	0.3208781

	0.2116302
	0.3429494
$\tilde{w}_3$	0.5255574

$\tilde{w}_4$	0.0971723
	0.1499303
	0.2476687

	0.1346716
	0.2208119
$\tilde{w}_5$	0.2152486

Now,it iscalculated thedefuzzified weight or non-fuzzy weight by using the equation (3.11), by Excel as follows:

$$w_1 = \frac{a_1 + b_1 + c_1}{3}$$

= (0.0638051+0.0940354+ 0.1544606)/3

w_1	0.1041

Similarly it can be calculate the other value, that is:

w_2	0.210509
w_3	0.360046
w_4	0.164924
w_5	0.190244

So the defuzzified weight of five main attributes:

w(TF,EF,RF,ENVF,POPUF) = (0.10410, 0.210509,0.360046, 0.164924,0.190244)

Now, normalization is performed to obtain the weights for each aspect and indicator by using Equation (3.12), as follows:

$W_1 = w_1 / (w_1 + w_2 + w_3 + w_4 + w_5)$

= 0.10410/ (0.10410+0.210509+, 0.360046+ 0.164924+0.190244)

W_1	0.10109

Similarly other normalized weight can be found out, that is :

W_2	0.20441
W_3	0.3496
W_4	0.16017
W_5	0.18476

So, finallythe normalizedweight is found for the main attributes with respect to goal as follows:

W (TF, EF, RF, ENVF, POPUF)= (0.10109, 0.20441, 0.3496, 0.16017,0.18476)

The Summary of Calculation is given bellow which is done by Excel, shown in table 4.4.

Table 4.4: Sample Calculation of normalized weight of main attributes WRT Goal

		SUM $\tilde{r}_i$				Defuzzified weight		Normalized weight	SUM W_i
	0.435807	4.27717		0.0638051	w_1	0.104041	W_1	0.10109	1.00
	0.513832	5.468173	$\tilde{w}_1$	0.0940354					
$\tilde{r}1$	0.660073	6.819836		0.1544606					
	0.808548			0.1183769	w_2	0.210371	W_2	0.20441	
	1.050625		$\tilde{w}_2$	0.192273					
$\tilde{r}2$	1.371243			0.3208781					
	1.445494			0.2116302	w_3	0.359746	W_3	0.3496	
	1.873958		$\tilde{w}_3$	0.3429494					
$\tilde{r}3$	2.245921			0.5255574					
	0.663714			0.0971723	w_4	*0.164838*	W_4	0.16017	
	0.819255		$\tilde{w}_4$	0.1499303					
$\tilde{r}4$	1.05839			0.2476687					
	0.919845			0.1346716	w_5	0.190139	W_5	0.18476	
	1.206569		$\tilde{w}_5$	0.2208119			SUM	1.00000	
$\tilde{r}5$	1.494655			0.2152486					

4.3 FuzzyAHP Calculation for sub-attributes

The sample of two pair wise comparison matrices with respect to the technological factor (TF) are given here:

Expert 1: Academician

Table 4.5: Pair wise comparison matrix of sub attributes WRT TF

	PDI			POC		
PDI	1.0000	1.0000	1.0000	0.3330	0.4000	0.5000
POC	2.0000	2.5000	3.0030	1.0000	1.0000	1.0000

Here, in this case there is no need to test the consistency of the matrix, as there is no possibility to inconsistence in answering.

Expert 1: Professional

Table 4.6: Pair wise comparison matrix of sub attributes WRT TF

	PDI			POC		
PDI	1.0000	1.0000	1.0000	0.5000	0.6670	1.0000
POC	1.0000	1.5000	2.0000	1.0000	1.0000	1.0000

So, the aggregated pair-wise comparison matrix with respect to main attributes TF can be calculated as mentioned above:

Table 4.7: Aggregated Pair wise comparison matrix of sub attributes TF

	PDI			POC		
PDI	1.0000	1.0000	1.0000	0.4178	0.5011	0.8128
POC	1.2303	1.9956	2.3935	1.0000	1.0000	1.0000

Now, it is calculated the priorities via the geometric means method for this pair wise comparison matrices is:

	0.64637
	0.70788
$\tilde{r}_1$	0.90155
	1.10920
	1.41266
$\tilde{r}_2$	1.54709

The Fuzzy weight of each Sub attributes WRT Technological Factor (TF):

	0.26397
	0.33382
$\tilde{w}_1$	0.51354
	0.45298
	0.66618
$\tilde{w}_2$	0.88125

Now,it is calculated the defuzzified weight as mentioned above.

w_1	0.37044
w_2	0.63929

Now, it is performed normalization to obtain the weights:

W_1	0.3669
W_2	0.6331

With respect to main attributes TF, the weight of sub-attributes is as below:

W (PDI, POC) = (0.3669, 0.6331)

The Summary of Calculation is given bellow which is done by Excel.

		SUM $\tilde{r}i$		
	0.6389	1.7876		0.269077
	0.7186	2.0751		0.346301
$\tilde{r}_1$	0.8409	2.3746	$\tilde{w}_1$	0.470394
	1.1487			0.483750
	1.3565			0.653699
$\tilde{r}_2$	1.5337		$\tilde{w}_2$	0.857932
			w_1	0.361924
			w_2	0.624518
			W_1	0.3669
			W_2	0.6331
			SUM W_i	1.0000

Similarly, with respect to main attributes EF, the weight of sub-attributes is as below:

W (ICR, GC) = (0.3428,0.6572)

With respect to main attributes RF, the weight of sub-attributes is as below:

W (AIR, SMP) = (0.6342, 0.3658)

With respect to main attributes ENVF, the weight of sub-attributes is as below:

W (IPENV, IL) = (0.3144, 0.6856)

With respect to main attributes POPUF, the weight of sub-attributes is as below:

W (POPDEN, APLOC) = (0.4448, 0.5552)

4.4 Fuzzy AHP Calculationfor alternatives

The sample of two matrices for the alternatives with respect to Plant Design and Installation complexity (PDI) are given here:

Expert 1: Academician

Table 4.8: Pair wise comparison matrix of Alternatives with Respect to PDI

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1.00	1.00	1.00	2.00	2.50	3.00	0.50	1.00	1.50	2.50	3.00	3.50	2.00	2.50	3.00
CFPP	0.33	0.40	0.50	1.00	1.00	1.00	0.40	0.50	0.67	1.00	1.50	2.00	1.50	2.00	2.50
OFPP	0.67	1.00	2.00	1.50	2.00	2.50	1.00	1.00	1.00	2.50	3.00	3.50	2.00	2.50	3.00
NPP	0.29	0.33	0.40	0.50	0.67	1.00	0.29	0.33	0.40	1.00	1.00	1.00	1.00	1.50	2.00
HPP	0.33	0.40	0.50	0.40	0.50	0.67	0.33	0.40	0.50	0.50	0.67	1.00	1.00	1.00	1.00

By Online CGI AHP Software

The Weight and CI:

Maximum Eigen Value =5.06064
C.I.=0.015159
Weights (Eigen Vector)
0.320214
0.160681
0.304339
0.114637
0.100129

CR = 0.0135<0.1,

So, Matrix is consistent.

Expert 1: Professional

Table 4.9: Pair wise comparison matrix of alternativesWRT PDI

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1.00	1.00	1.00	2.00	2.50	3.00	1.00	1.50	2.00	2.50	3.00	3.50	2.00	2.50	3.00
CFPP	0.33	0.40	0.50	1.00	1.00	1.00	0.67	1.00	2.00	1.00	1.50	2.00	2.00	2.50	3.00
OFPP	0.50	0.67	1.00	0.50	1.00	1.49	1.00	1.00	1.00	2.50	3.00	3.50	2.00	2.50	3.00
NPP	0.29	0.33	0.40	0.50	0.67	1.00	0.29	0.33	0.40	1.00	1.00	1.00	1.00	1.50	2.00
HPP	0.33	0.40	0.50	0.33	0.40	0.50	0.33	0.40	0.50	0.50	0.67	1.00	1.00	1.00	1.00

By Online CGI AHP Software

The Weight and CI:

Maximum Eigen Value =5.10741
C.I.=0.0268534

Weights (Eigen Vector)

0.349822
0.193985
0.245942
0.114721
0.0955298

CR = 0.0239<0.1.

So Matrix is consistent.

So, the aggregated pair-wise comparison matrix for the Alternatives with respect to PDI is as in table 4.10 as follows:

Table 4.10: Aggregated Pair wise comparison matrix of alternatives WRT PDI

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1.000	1.000	1.000	1.951	2.432	2.924	0.482	0.978	1.475	2.482	2.983	3.477	1.975	2.469	2.986
CFPP	0.342	0.411	0.513	1.000	1.000	1.000	0.389	0.483	0.642	0.976	1.479	1.979	1.469	1.958	2.485
OFPP	0.678	1.022	2.074	1.557	2.073	2.568	1.000	1.000	1.000	2.479	2.979	3.479	1.965	2.479	2.979
NPP	0.288	0.335	0.403	0.505	0.676	1.025	0.287	0.336	0.403	1.000	1.000	1.000	0.985	1.476	1.976
HPP	0.335	0.405	0.506	0.402	0.511	0.681	0.336	0.403	0.509	0.506	0.678	1.015	1.000	1.000	1.000

By following the similar process of calculation, as it is done above, the normalized weight of alternatives with respect to Plant Design and Installation Complexity (PDI)

W (GFPL, CFPP, OFPP, NPP, HPP)= (0.31426, 0.16166,0.31988,0.11754,0.08666)

The remaining nine (9) aggregated matrix is given in Appendix A.

Similarly, it is calculated the normalized weight of alternatives with respect to Plant Operational Complexity (POC):

W (GFPL, CFPP, OFPP, NPP, HPP) = (0.27413,0.16933,0.31494,0.09113,0.15046)

The normalized weight of alternatives with respect to Initial cost and Royalty (ICR):

W (GFPL, CFPP, OFPP, NPP, HPP)= (0.25995,0.21602,0.29134,0.1517,0.08098)

The normalized weight of alternatives with respect to Generation Cost (GC):

W (GFPL, CFPP, OFPP, NPP, HPP)= (0.14618,0.29406,0.07529,0.28641,0.19806)

The normalized weight of alternatives with respect to Availability of Input Resource (AIR):

W (GFPL, CFPP, OFPP, NPP, HPP)=(0.25184,0.39864,0.09681,0.174,0.07871)

The normalized weight of alternatives with respect to Availability of skilled manpower (SMP):

W (GFPL, CFPP, OFPP, NPP, HPP)= (0.22853,0.24076,0.25409,0.09194,0.18467)

The normalized weight of alternatives with respect to impact on Physical environment (IPENV):

W (GFPL, CFPP, OFPP, NPP, HPP)= (0.26016,0.12951,0.21227,0.13369,0.26437)

The normalized weight of alternatives with respect to impact on life (IL):

W (GFPL, CFPP, OFPP, NPP, HPP)=(0.31464,0.14518,0.21508,0.09464,0.23045)

The normalized weight of alternatives with respect to Population Density (POPDEN):

W (GFPL, CFPP, OFPP, NPP, HPP)= (0.19051,0.19089,0.1634,0.37861,0.0762)

The normalized weight of alternatives with respect to Appropriate Location (APLOC):

W (GFPL, CFPP, OFPP, NPP, HPP)= (0.29856,0.15925,0.28883,0.16262,0.07659)

AIR	Availability of Input Resources	APLOC	Appropriate Plant Location
GC	Generation Cost	IL	Impact on Life
IPENV	Impact on Physical Environment	PDI	Plant Design and Installation Complexity
POC	Plant Operational Complexity	POPDEN	Population Density
SMP	Skilled Man Power	ENVF	Environmental Factor
EF	Economic Factor	POPUF	Population Factor
RF	Resource Factor	TF	Technological Factor
CFPP	Coal Fired Power Plant	GFPP	Gas Fired Power Plant
HPP	Hydro Power Generation Plant	NPP	Nuclear Power Plant
OFPP	Oil Fired Power Plant	ICR	Initial Cost and Royalty

4.5 Calculation of Global Weight

The summarization of individual attributes and their weight has been given in table 4.11.

Table 4.11: Weight of Individual Attributes

	TF	EF		RF		ENVF		POPUF	
	0.10109	0.20441		0.3496		0.16017		0.18476	
PDI	POC	ICR	GC	AIR	SMP	IPENV	IL	POPDEN	APLOC
0.3669	0.6331	0.3428	0.6572	0.634	0.3658	0.3144	0.6856	0.4448	0.5552
0.31426	0.27413	0.26	0.1462	0.252	0.22853	0.26016	0.31464	0.19051	0.29856
0.16166	0.16933	0.216	0.2941	0.399	0.24076	0.12951	0.14518	0.19089	0.15925
0.31988	0.31494	0.2913	0.0753	0.097	0.25409	0.21227	0.21508	0.1634	0.28883
0.11754	0.09113	0.1517	0.2864	0.174	0.09194	0.13369	0.09464	0.37861	0.16262
0.08666	0.15046	0.081	0.1981	0.079	0.18467	0.26437	0.23045	0.0762	0.07659

For the priority ranking of power generation methods, calculation of global weight is necessary. The sample calculation of Global Weight is shown below:

For global weight of GFPP = Weight of (TF*PDI*GFPP+TF*POC*GFPP*+EF *ICR*GFPP+EF*GC*GFPP+ RF*AIR*GFPP+ RF*SMP*GFPP+ ENVF* IPENV*GFPP+ENVF*IL*GFPP+ OPUF*POPDEN*GFPP+POPUF*APLOC*GFPP)**

By using this formula and using Excel work sheet we can calculate the global weight of different power generation method as shown in table 4.12 and Fig. 4.1.

Table: 4.12: Global weight of Power Generation Method

		TF	EF		RF		ENVF		POPUF	
		0.10109	0.20441		0.3496		0.16017		0.18476	
	PDI	POC	ICR	GC	AIR	SMP	IPENV	IL	POPDEN	APLOC
	0.3669	0.6331	0.3428	0.6572	0.634	0.3658	0.3144	0.6856	0.4448	0.5552
GFPP	0.31426	0.27413	0.26	0.1462	0.252	0.22853	0.26016	0.31464	0.19051	0.29856
CFPP	0.16166	0.16933	0.216	0.2941	0.399	0.24076	0.12951	0.14518	0.19089	0.15925
OFPP	0.31988	0.31494	0.2913	0.0753	0.097	0.25409	0.21227	0.21508	0.1634	0.28883
NPP	0.11754	0.09113	0.1517	0.2864	0.174	0.09194	0.13369	0.09464	0.37861	0.16262
HPP	0.08666	0.15046	0.081	0.1981	0.079	0.18467	0.26437	0.23045	0.0762	0.07659

Weight GFPP	Weight CFPP	Weight OFPP	Weight NPP	Weight HPP
0.011655879	0.005995957	0.011864324	0.004359549	0.00321421
0.017544342	0.010837133	0.020156185	0.005832327	0.00962945
0.018215151	0.015136899	0.020414703	0.010629884	0.00567441
0.019637566	0.039503506	0.010114327	0.038475819	0.02660703
0.055830649	0.088374881	0.021461901	0.038574226	0.01744929
0.029221914	0.030785752	0.032490246	0.01175628	0.02361358
0.013100994	0.006521793	0.010689375	0.006732287	0.013313
0.034551421	0.015942586	0.023618484	0.01039266	0.0253063
0.01565635	0.015687578	0.013428416	0.031114642	0.00626221
0.030625912	0.016335666	0.029627821	0.007856507	0.00785651
Global Weight				
0.246040176	0.245121753	0.193865782	0.165724181	0.138926000

**

AIR	Availability of Input Resources	APLOC	Appropriate Plant Location
GC	Generation Cost	IL	Impact on Life
IPENV	Impact on Physical Environment	PDI	Plant Design and Installation Complexity
POC	Plant Operational Complexity	POPDEN	Population Density
SMP	Skilled Man Power	ENVF	Environmental Factor
EF	Economic Factor	POPUF	Population Factor
RF	Resource Factor	TF	Technological Factor
CFPP	Coal Fired Power Plant	GFPP	Gas Fired Power Plant
HPP	Hydro Power Generation Plant	NPP	Nuclear Power Plant
OFPP	Oil Fired Power Plant	ICR	Initial Cost and Royalty

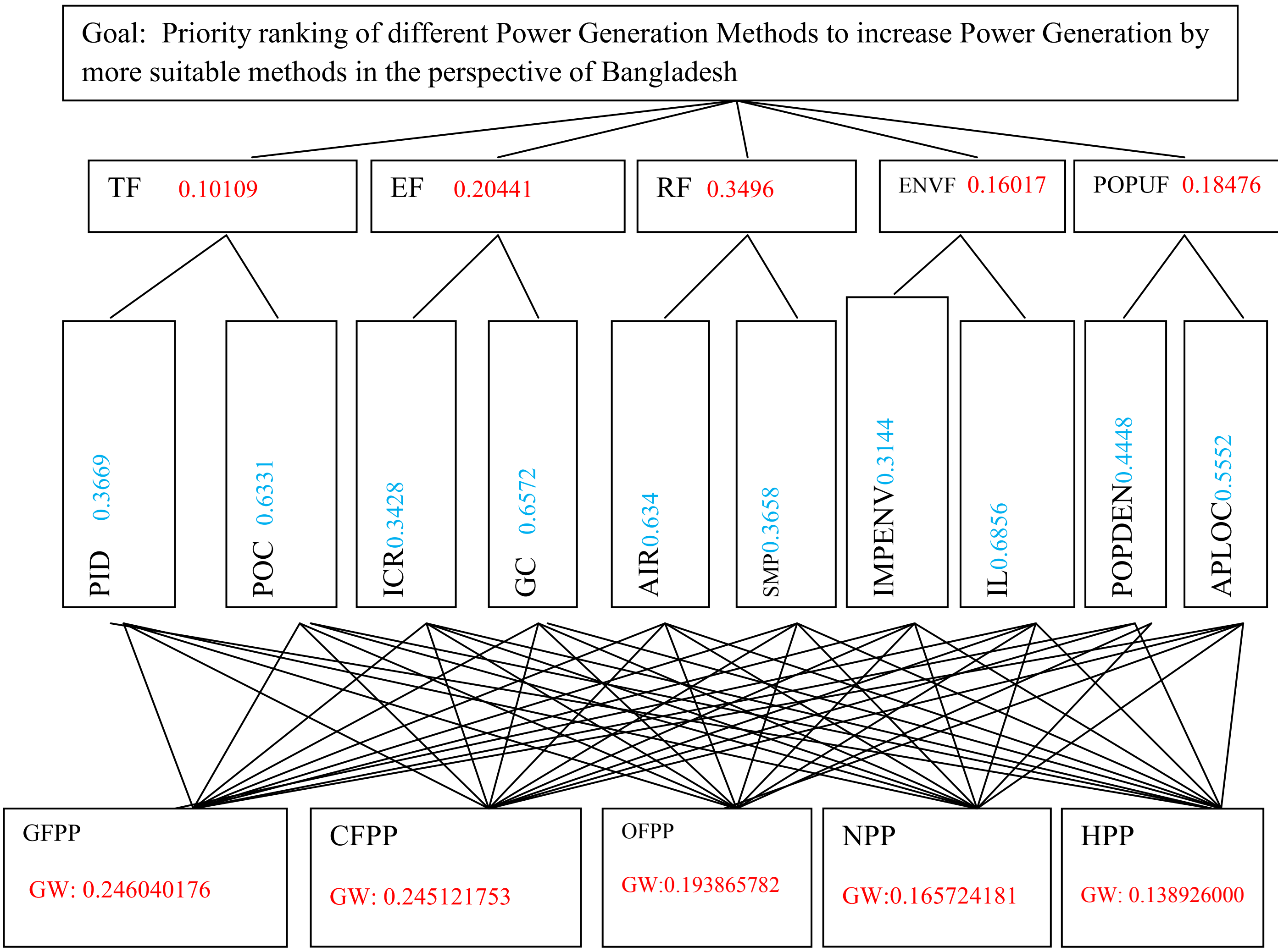


Figure 4.1: Weight of each main and sub attributes and alternatives

The bar chart of global weight of different power generation method which is included in this study is shown in the table 4.13 and figure 4.2.

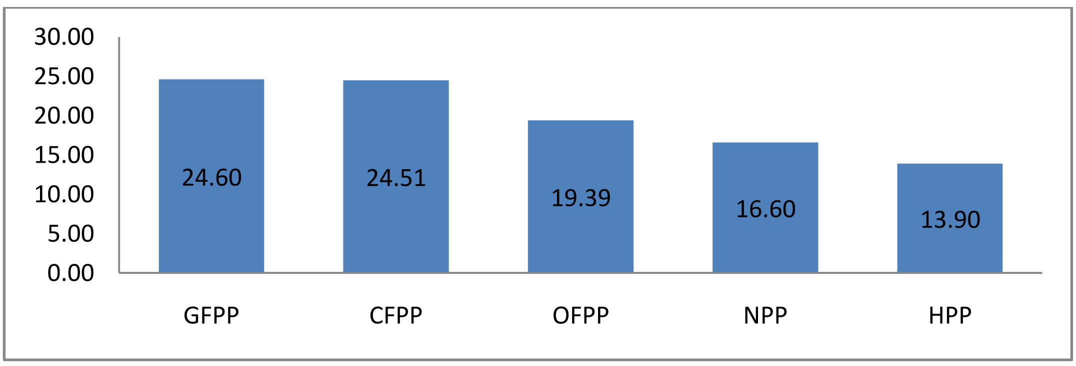


Figure4.2: Global weight of power generation method

Table 4.13: Priority Ranking Table of Power Generation Methods

Power Gen. Methods/Plants	Global Weight	Rank	Preference WRT Global Weight
GFPP	0.246040176	1st	24.60
CFPP	0.245121753	2nd	24.51
OFPP	0.193865782	3rd	19.39
NPP	0.165724181	4th	16.60
HPP	0.138926000	5th	13.90

The Fuzzy AHP preference according to this study with respect to global weight and the present generation in percentage of the five alternatives are shown in the fig 4.3:

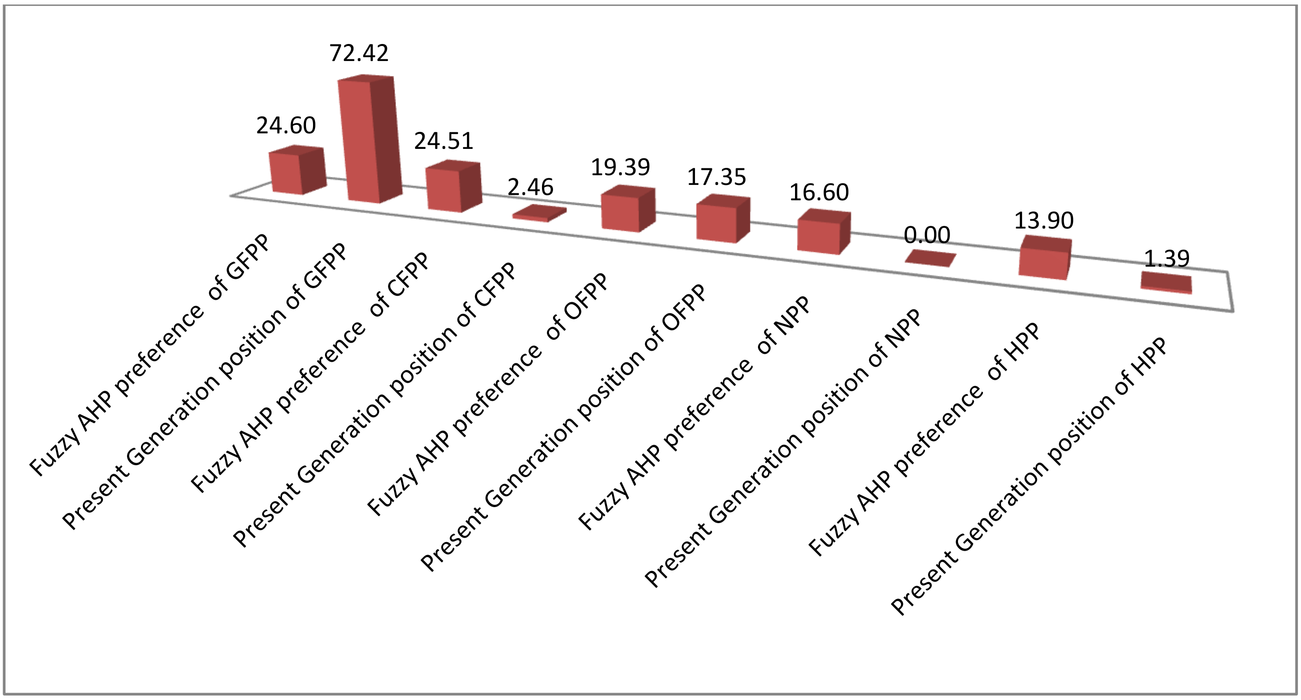


Figure4.3: Fuzzy AHP preference verses Present Generation position

4.6 Discussion

This empirical research has focused on the integration of technical, economic, environmental, population and resource aspects related to the planning of energy generation methods in the perspectives of Bangladesh to meet the future demand; in other words, to investigate if the use of multi-criteria decision making (MCDM) is appropriate for energy generation planning. Energy generation planning problems are generally characterized by multiple decision-makers (DMs), several conflicting criteria, and many sources of uncertainty, long time frames, and capital-intensive investments, all of which are characteristics that should make this planning problem particularly suitable for the use of MCDM.

One main reason to apply MCDM method"s Fuzzy AHP tool instead of classical cost optimization is that the use of MCDM Fuzzy AHP is supposed to give the DM a better view of the alternatives and clarifies the decision-making process for him. MCDM Fuzzy AHP provides an extensive framework where all relevant information about the problem can be organized, which allows for a structure, analysis and openness to complex problems. In addition, the MCDM method"s Fuzzy AHP way of formulatingproblems often increases discussions among stakeholders, activates people who are not normally participants, and shifts the focus towards the most relevant problem issues. The result is that the DM will learn how to recognize and solve conflicts that are based on misunderstandings among the parties, and learn that a problem can be studied fromseveral points of view.

Another important advantage of MCDM method"s Fuzzy AHP in preference to some other decision methodologies is its documentation. All relevant data, uncertainties and preferences are documented and can be revised, meaning that a DM – after performing the analysis – will know in detail why one particular alternative was preferred. This is important for increasing the DMs" confidence in the decision, since they can document that their decisions have been thoroughly considered and that the chosen alternative is the best alternative when considering all factors. Such confidence is considered to be very important in the successful implementation of the chosen solution. On the other hand, more responsibility is left to the DM, who has to specify his priorities, criteria weights and risk attitude to address uncertainties inherent in the planning problem.

The literature provides several examples of the use of MCDM for energy-planning purposes. However, not much work seems to have been done yet on the use of MCDM method"s Fuzzy AHP in energy generation planning; particularly not when multiple energy generation methods are involved.

The work with this thesis has shown that for the successful implementation of MCDM, it is essential that the problem is properly structured before the preference elicitation interviews are accomplished. However, it is often difficult for an analyst to define a set of criteria/attributes that is able to represent the entire set of the DM‟s objectives, where all criteria are easily understood by the DM, and where there is no double counting of any impacts. To avoid that the analyst‟s own preferences are becoming visible, it is important that the analyst is not too creative – without prior discussion withthe DM – when determining the decision criteria. Especially inclusion of proxy criteria and proxy attributes can easily result in confusion. If preferences are elicited when there are misunderstandings between the DM and the analyst, it is not likely that the methodology will be able to elicit the DM‟s actual preferences. However, in this study it is tried to find put the best possible criteria/attributes to get more reliable result.

The key points which have to remember for the MCDM problem research like future energy mix planning is:

• Future energy generation planning problems are generally characterized by several conflicting criteria.
• Multi-criteria decision Making (MCDM) are designed for the identification of the best solution when considering several criteria, by calculating weights/scores that reflect the total value of each of the proposed alternatives.
•MCDM lets the decision maker (DM) explicitly express his preferences of the various criteria and provides a representation of the DM‟s subjective values and preferences.
•Many MCDM methods have the possibility of including qualitative criteria in a consistent way. For an energy generation planning project to be successful, it is essential to spend sufficient time and resources on problem definition and structuring, to ensure that there are no disagreements or confusion among the various DMs and the analyst regarding the nature of the problem and the desired goals.
• Due to the large amount of data that must be studied and processed in local energy generation planning problems, the use of an energy generation methods model might be advantageous or even necessary to determine the impacts of each decision alternative. However, an energy generation system model cannot always determine all impacts relevant for the analysis.

It is often difficult to decide which impacts are relevant to the analysis, and which can be disregarded. In this study it is tried to (1) include all effects that change as a consequence of the decision; (2) make sure that all the decision alternatives are treated consistently;

(3) avoid double-counting of impacts; and (4) was careful with the use of proxy criteria and proxy attributes.

The calculated result which is found here has well matched with the policies/action plan taken by the Government of Bangladesh. According to the PSMP of Bangladesh, by 2030; the power generation by Coal fired Power Generation will be increased from 2.46% to 51.0% (domestic and imported coal), the power generation by Gas Fired Power Generation will be reduced from 72.42% to 23.0% (Gas and LNG), the Nuclear Power Generation will be increased from 0.0% to 10.0%. However Oil Fired and Hydro power generation has got more importance according to this thesis than the PSMP(Oil, Hydro and Renewable: 7%, Regional Grid: 9%).The reason of this is: In MCDM different attributes including environmental, economic, and social and other issues are considered for ranking. This reason is also true for getting the high global weight of Gas Fired Power generation Method.

5. CONCLUTION

5.1 Conclusion

The purpose of this thesis is Priority ranking of different Power Generation Methods in the perspective of Bangladesh based on Fuzzy AHP calculations. In this study, five alternatives : Coal Fired Power Generation method, Gas Fired Power Generation method, Nuclear Power Generation method, Oil Fired Power Generation method, Hydro Power Generation method were selected . For Evaluation and ranking the five main attributes of Technological Factor, Economic Factor, Resource Factor, Environmental Factor, Population Factor; ten sub attributes: Plant Design and Installation Complexity, Plant Operational Complexity, Initial Cost and Royalty, Generation Cost, Availability of Input Resources, Skilled Man Power, Impact on Physical Environment, Impact on Life, Population Density, Appropriate Plant Location technological were considered. Through content analysis and a questionnaire survey, different power generation methods, main attributes and sub-attributes were identified and the structured hierarchy was formed. AHP method due to its use of unbalanced scale of judgments and its inability to adequately handle the inherent uncertainty and carelessness in the pair-wise comparison process is criticized. To overcome all these shortcomings and respect to ambiguity and complexity of human decision-making process, fuzzy AHP technology assessment tool is used.

The research findings can be summarized as: based on empirical data, the Gas Fired Power Generation method has got rank 1 with priority weights 24.60. However, for this type of power generation method requires natural gas as input. So, availability of natural gas is prime consideration in this case. Almost equal global priority weights of Coal Fired Power generation method which is 24.51 with rank 2.The 3rd rank is Oil Fired Power Generation method with priority weights 19.39, Nuclear and Hydro Power Generation method has got 4th and 5th rank with priority weights 16.60 and 13.90 respectively.

But the present power generation mix scenario of Bangladesh is different from the outcome of the research. Now, about 72.42 percent power is generated by Gas Fired Power Plant, only 2.46 percent by Coal Fired Power Plants, 19.35 percent by Oil Fired Power plant, 0 percentby Nuclear Power Plant and1.39 percentby Hydro Power Plant.

Based on the result of this research the DM‟s may rethink about power generation mix in energy planning of Bangladesh.

This study has been done for the situation of Bangladesh in energy generation mix planning. However, this method can be used in any other environment or country, by inputting the importance weights of attributes/sub-attributes for that environment or country. The validity of the data should be tested for those local conditions.

This study was conducted during the period from 2014 to 2016. However, as the socio-economic change is very slow and the commercialization of other alternatives will take a long time. As such the results shall hold good for a minimum of another ten to fifteen years.

However, it is important to realize that there is not one solution for how to do this, that is valid for all kind of energy generation mix planning MCDM problems. It is therefore necessary for the DM‟s and the analyst to discuss these issues before entering the decision-making phase.

5.2Recommendations

Based on the result which is found from this empirical research of MCDM problem, the following recommendations are emphasized:

►Power Generation by Coal in Bangladesh should be given the highest preference to increase thepresent generation capacityfrom 2.46percentto 24.51percent. So,Bangladesh should take intensive initiative to generate power by Coal immediately with the sophisticated Coal fired Power Generation Plants.

► Dependency on Power Generation by Gas should be reduced from present 72.42 percent to 24.6 percent as the gas reserve is in alarming situation.

►Nuclear power generation in Bangladesh perspective may be considered for cheaper unit generation cost and huge generation capacity with small plant but with highest consideration about safety.

► Hydro Power proportion may be increased by small Hydro Power plant and importing from neighboring potential countries.

5.3Scope for Future Work

The future researchers may include more attributes/criteria/alternatives for the priority ranking of power generation method by extending the present research work. The researchers may also measure and validate the results of present study by conducting research in the same perspective. The researchers may also conduct the research by other Fuzzy AHP method like Fuzzy Analytical Network Process(Fuzzy ANP) or other MCDM methods like the weighted product model (WPM), the weighted sum model (WSM), Aggregated Indices Randomization Method (AIRM),Technique for the Order of Prioritization by Similarity to Ideal Solution (TOPSIS). The results which are found by other method/methods may be compared/validated with the result which has been foundin this research.

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Appendix A

Pair Wise Comparison Matrices

Aggregated Pair wise Comparison Matrices

Pair wise comparison Matrix for the Main Attributes with respect (WRT) to goal:

	TF			EF			RF			ENVF			POPUF		
TF	1	1	1	0.38	0.47	0.64	0.27	0.33	0.48	0.39	0.48	0.64	0.39	0.48	0.64
EF	1.57	2.12	2.61	1	1	1	0.47	0.65	0.97	0.96	1.47	1.97	0.48	0.63	0.98
RF	2.08	3.05	3.66	1.03	1.54	2.11	1	1	1	1.99	2.48	2.98	1.48	1.98	2.48
ENVF	1.56	2.08	2.58	0.51	0.68	1.04	0.34	0.4	0.5	1	1	1	0.49	0.65	0.98
POPUF	1.57	2.08	2.58	1.03	1.58	2.08	0.4	0.51	0.68	1.02	1.54	2.06	1	1	1

Pair wise comparison matrix of sub attributes with respect to EF:

	PDI			POC		
PDI	1	1	1	0.31	0.39	0.48
POC	1.99	2.46	1.98	1	1	1

Pair wise comparison matrix of sub attributes with respect to RF:

	AIR			SMP		
AIR	1	1	1	2.49	2.99	3.49
SMP	0.29	0.33	0.4	1	1	1

Pair wise comparison matrix of sub attributes with respect to ENVF:

	IPENV			IL		
IPENV	1	1	1	0.31	0.38	0.48
IL	1.99	2.48	2.96	1	1	1

Pair wise comparison matrix of sub attributes with respect to POPUF:

	IPENV			IL		
IPENV	1	1	1	0.47	0.97	1.47
IL	0.63	0.97	1.97	1	1	1

Aggregated Pair wise comparison matrix of alternatives WRT PDI:

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	1.95	2.43	2.92	0.48	0.98	1.48	2.48	2.98	3.48	1.98	2.47	2.99
CFPP	0.34	0.41	0.51	1	1	1	0.39	0.48	0.64	0.98	1.48	1.98	1.47	1.96	2.49
OFPP	0.68	1.02	2.07	1.56	2.07	2.57	1	1	1	2.48	2.98	3.48	1.97	2.48	2.98
NPP	0.29	0.34	0.4	0.51	0.68	1.03	0.29	0.34	0.4	1	1	1	0.99	1.48	1.98
HPP	0.34	0.41	0.51	0.4	0.51	0.68	0.34	0.4	0.51	0.51	0.68	1.02	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to Plant operational Complication (POC):

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	1.47	1.98	2.48	0.48	0.99	1.48	1.98	2.49	2.98	1	1.48	1.97
CFPP	0.4	0.51	0.68	1	1	1	0.47	0.64	0.99	1.98	2.48	2.98	0.48	0.63	0.98
OFPP	0.68	1.02	2.09	1.02	1.57	2.14	1	1	1	2.47	2.97	3.45	1.96	2.48	2.94
NPP	0.34	0.4	0.51	0.34	0.4	0.51	0.29	0.34	0.41	1	1	1	0.39	0.48	0.65
HPP	0.51	0.68	1.01	1.03	1.58	2.09	0.34	0.4	0.51	1.54	2.07	2.58	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to ICR:

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	0.48	0.98	1.48	0.64	0.99	1.98	1.48	1.98	2.48	1.98	2.48	2.97
CFPP	0.68	1.02	2.09	1	1	1	0.39	0.47	0.65	0.99	1.47	1.95	1.98	2.47	2.98
OFPP	0.51	1.02	1.57	1.55	2.13	2.6	1	1	1	1.96	2.47	2.95	1.46	1.97	2.45
NPP	0.4	0.5	0.68	0.51	0.68	1.01	0.34	0.41	0.51	1	1	1	1.97	2.47	2.97
HPP	0.34	0.4	0.5	0.34	0.41	0.51	0.41	0.51	0.69	0.34	0.4	0.51	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to GC:

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	0.31	0.39	0.49	2.44	2.96	3.42	1.96	2.47	2.96	2.49	2.99	3.47
CFPP	1.58	2.07	2.6	1	1	1	2.47	2.97	3.45	1.98	2.47	2.95	2.49	2.99	3.47
OFPP	0.29	0.34	0.41	0.29	0.34	0.41	1	1	1	0.47	0.98	1.48	0.47	0.98	1.48
NPP	0.34	0.41	0.51	0.34	0.41	0.51	0.68	1.01	2.06	1	1	1	0.48	0.64	0.98
HPP	0.41	0.51	0.67	0.41	0.51	0.68	1.03	1.57	2.09	1.03	1.57	2.09	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to AIR :

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	0.28	0.31	0.38	2.44	2.96	3.42	1.96	2.47	2.96	2.49	2.99	3.47
CFPP	2.66	3.2	3.63	1	1	1	2.47	2.97	3.45	1.98	2.47	2.95	2.49	2.99	3.47
OFPP	0.29	0.34	0.41	0.29	0.34	0.41	1	1	1	0.39	0.48	0.64	0.47	0.98	1.48
NPP	0.34	0.4	0.51	0.34	0.41	0.51	1.57	2.1	2.59	1	1	1	2.49	2.98	3.45
HPP	0.29	0.33	0.4	0.29	0.33	0.4	0.68	1.02	2.11	0.29	0.34	0.4	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to SMP:

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	0.48	0.98	1.48	0.48	0.98	1.48	1.99	2.47	2.97	0.48	0.98	1.48
CFPP	0.68	1.03	2.09	1	1	1	0.48	0.98	1.48	1.99	2.47	2.97	0.48	0.98	1.48
OFPP	0.68	1.03	2.09	0.68	1.03	2.09	1	1	1	1.98	2.48	2.99	0.48	0.98	1.48
NPP	0.34	0.41	0.5	0.34	0.41	0.5	0.33	0.4	0.5	1	1	1	0.31	0.38	0.48
HPP	0.68	1.03	2.09	0.68	1.03	2.09	0.68	1.03	2.09	2.1	2.6	3.2	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to IPENV:

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	1.98	2.48	2.98	0.98	1.48	1.98	1.98	2.48	2.98	0.39	0.48	0.64
CFPP	0.34	0.4	0.51	1	1	1	0.48	0.64	0.98	0.64	0.98	1.98	0.31	0.38	0.48
OFPP	0.51	0.68	1.03	1.02	1.56	2.1	1	1	1	1.48	1.97	2.46	0.48	0.63	0.98
NPP	0.34	0.4	0.51	0.51	1.03	1.55	0.41	0.51	0.67	1	1	1	0.49	0.64	0.98
HPP	1.57	2.1	2.58	2.07	2.64	3.2	1.02	1.58	2.09	1.03	1.57	2.06	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to IL:

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	1.48	1.98	2.48	0.99	1.47	1.97	2.47	2.97	3.43	0.98	1.47	1.97
CFPP	0.4	0.51	0.68	1	1	1	0.38	0.48	0.63	1.99	2.48	1.98	0.38	0.48	0.63
OFPP	0.51	0.68	1.01	1.58	2.1	2.66	1	1	1	1.99	2.49	2.98	0.37	0.47	0.63
NPP	0.29	0.34	0.4	0.5	0.4	0.5	0.34	0.4	0.5	1	1	1	0.37	0.47	0.63
HPP	0.51	0.68	1.03	1.58	2.09	2.64	1.58	2.11	2.67	1.58	2.11	2.67	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to POPUDEN:

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	0.98	1.47	1.96	0.48	0.98	1.47	0.31	0.39	0.49	1.98	2.49	2.97
CFPP	0.51	0.68	1.02	1	1	1	1.48	1.98	2.47	0.31	0.39	0.49	1.98	2.47	2.97
OFPP	0.68	1.03	2.1	0.41	0.51	0.68	1	1	1	0.31	0.39	0.49	1.98	2.47	2.97
NPP	2.06	2.58	3.2	2.06	2.58	3.2	2.06	2.58	3.2	1	1	1	1.98	2.47	2.97
HPP	0.34	0.4	0.51	0.34	0.41	0.51	0.34	0.41	0.51	0.34	0.41	0.51	1	1	1

Pair wise Comparison aggregated matrix for the alternatives with respect to APLOC:

	GFPP			CFPP			OFPP			NPP			HPP		
GFPP	1	1	1	1.48	1.98	2.47	0.48	0.98	1.48	1.98	2.48	2.97	1.98	2.48	2.97
CFPP	0.4	0.51	0.68	1	1	1	0.38	0.48	0.63	0.47	0.98	1.45	1.47	1.98	2.47
OFPP	0.68	1.03	2.1	1.58	2.1	2.64	1	1	1	1.47	1.98	2.47	1.98	1.98	1.98
NPP	0.34	0.4	0.51	0.69	1.03	2.15	0.41	0.51	0.68	1	1	1	1.47	1.98	2.47
HPP	0.34	0.4	0.51	0.41	0.51	0.68	0.51	0.51	0.51	0.41	0.51	0.68	1	1	1

Appendix B

FULL QUESTIONNAIRE

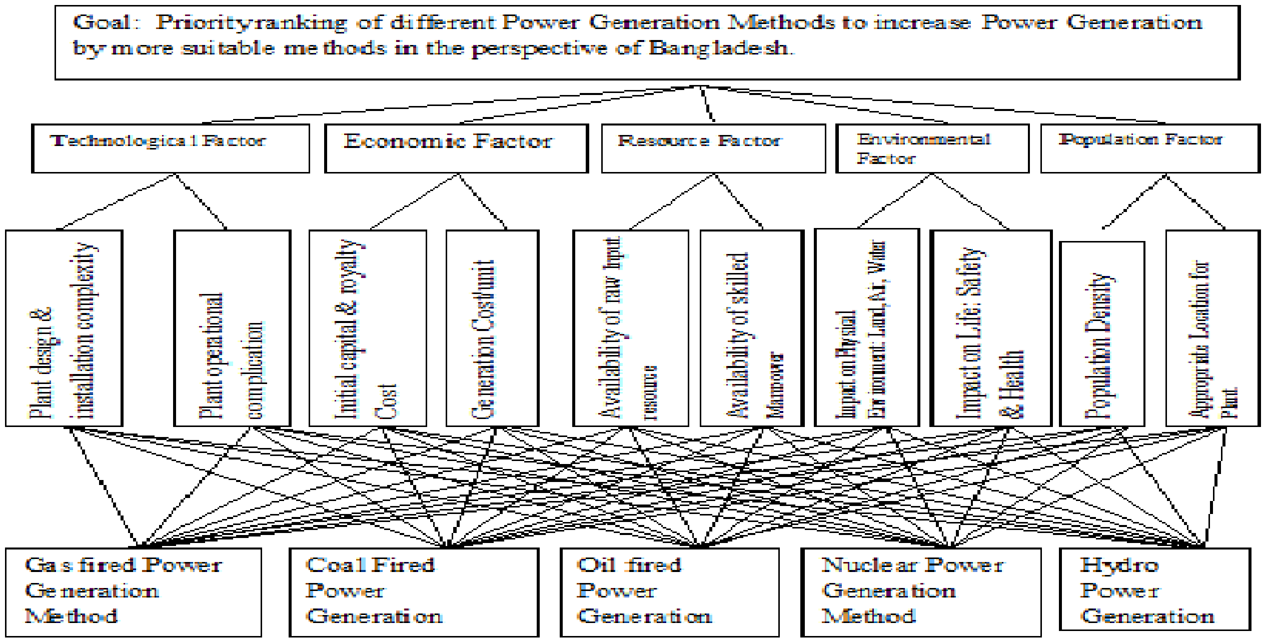

Figure: Hierarchical decomposition of criteria, sub criteria and alternatives

Triangular Scale for Triangular Fuzzy number (TFN) conversion (Büyüközkan et al., 2004)

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

QUESTIONNAIRE

Please read the following questions and put check marks on the pair wise comparison matrices.

► If the attribute of „LHS" is more important/preferable than the right hand side (RHS) attribute with respect to the element on which it is compared , then use proper scale of left hand side (LHS).
► If the attribute of „RHS" is more important/preferable than the Left hand side (RHS) attribute with respect to the element on which it is compared, then use proper scale of right hand side (RHS).

A. With respect to overall Goal "Priority Ranking of Power Generation Methods (Coal, Gas, Oil, Nuclear, Hydro) to increase Power Generation Capacity by more suitable Methods in the Perspective of Bangladesh to meet the present and future demand",

Q1. How important/preferable is Technological Factor (TF) when it is compared with Economic Factor (EF)?

Q2. How important/preferable is Technological Factor (TF) when it is compared with Resource Factor (RF)?

Q3. How important/preferable is Technological Factor (TF) when it is compared with Environmental Factor (ENVF)?

Q4. How important/preferable is Technological Factor (TF) when it is compared with Population Factor (POPUF)?

Q5. How important/preferable is Economic Factor (EF) when it is compared with Resource Factor (RF)?

Q4. How important/preferable is Technological Factor (TF) when it is compared with Population Factor (POPUF)?

Q6. How important/preferable is Economic Factor (EF) when it is compared with Environmental Factor (ENVF)?

Q7. How important/preferable is Economic Factor (TF) when it is compared with Population Factor (POPUF)?

Q8. How important is Resource Factor (RF) when it is compared with Population Factor (POPUF)?

Q9. How important/preferable is Technological Factor (TF) when it is compared with Environmental Factor (ENVF)?

Q10. How important/preferable is Environmental Factor (ENVF) when it is compared with Population Factor (POPUF)?

With respect to overall Goal.*		Importance (or Preference) of one main –attributes over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More Important	Very Strongly More	Strongly More Important	Weakly More Important	Equally Important	Just Equal	Equally Important	Weakly More Important	Strongly More Important	Very Strongly More	Absolutely More Important	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	TF												EF
Q2	TF												RF
Q3	TF												ENVF
Q4	TF												POPUF
Q5	EF												RF
Q6	EF												ENVF
Q7	EF												POPUF
Q8	RF												ENVF
Q9	RF												POPUF
Q10	ENVF												POPUF

B. With respect to main attribute "Technological Factor (TF)",

Q1. How important/preferable is Plant design & Installation Complexity (PDI) when it is compared with Plant Operational Complication (POC)?

With respect to Technological Factor (TF)		Importance (or Preference) of one sub –attributes over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	Just Equal	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	PDI												POC

C. With respect to main attribute “Economic Factor (EF)”,

Q1. How important/preferable is Initial Capital & Royalty Cost (ICR) when it is compared with Generation Cost per unit (GC)?

With respect to Economic Factor (EF)		Importance (or Preference) of one sub –attributes over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
than attributes of RHS								than attributes of LHS					
Q1	ICR												GC

D. With respect to main attribute “Resource Factor (RF)”,

Q1. How important/preferable is Availability of raw Input Resource (AIR) when it is compared with Availability of Skilled Manpower (SMP)?

With respect to Resource Factor (RF)		Importance (or Preference) of one sub –attributes over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
than attributes of RHS								than attributes of LHS					
Q1	AIR												SMP

E. With respect to main attribute “Environmental Factor (ENVF)”,

Q1. How important/preferable is Impact on Physical Environment (IPENV): air, water, land, when it is compared with Impact on Life (IL): Safety & Health?

With respect to Environmental Factor (ENVF)		Importance (or Preference) of one sub –attributes over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	IPENV												IL

F. With respect to main attribute "Population Factor (POPUF)",

Q1. How important/preferable is Population Density (PODEN) when it is compared with Appropriate Location for Plant (APLOC)?

With respect to Population Factor (POPUF)		Importance (or Preference) of one sub –attributes over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	POPDEN												APLOC

G. With respect to sub attribute "Plant design & Installation Complexity (PDI)",

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Plant design & Installation Complexity (PDI)		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

H. With respect to sub attribute “Plant Operational Complication (POC)**”,**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Plant Operational Complication (POC)		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
than attributes of RHS							than attributes of LHS						
Q1	GFPP												CFPP
Q2	GFPP												OFPP

Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

I. With respect to sub attribute "Initial Capital & Royalty Cost (ICR)**",**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Initial Capital & Royalty Cost (ICR)		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

J. With respect to sub attribute “Generation Cost per unit (GC)**”,**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Generation Cost per unit (GC)		Importance (or Preference) of one method over another												
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

K. With respect to sub attribute “Availability of raw Input Resource (AIR)**”,**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Availability of raw Input Resource (AIR)		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP

Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

L. With respect to sub attribute "Availability of Skilled Manpower (SMP)**",**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Availability of Skilled Manpower (SMP)		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

M. With respect to sub attribute "Impact on Physical Environment (IPENV)**",**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Impact on Physical Environment (IPENV)		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

N. With respect to sub attribute "Impact on Life (IL): Safety & Health**",**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Impact on Life (IL): Safety & Health		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP

Q9	OFPP												HPP
Q10	NPP												HPP

O. With respect to sub attribute "Population Density (PODEN)"**,**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Population Density (PODEN)		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					

Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP

P. With respect to sub attribute "Appropriate Location for Plant (APLOC)**",**

Q1. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Fired Power Plant (CFPP)?

Q2. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q3 How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Coal Nuclear Power Plant (NPP)?

Q4. How important/preferable is Gas Fired Power Plant (GFPP) when it is compared with Hydro Power Plant (HPP)?

Q5. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Oil Fired Power Plant (OFPP)?

Q6. How important is Coal Fired Power Plant (CFPP) when it is compared with Oil Nuclear Power Plant (NPP)?

Q7. How important/preferable is Coal Fired Power Plant (CFPP) when it is compared with Hydro Power Plant (HPP)?

Q8. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Nuclear Power Plant (NPP)?

Q9. How important/preferable is Oil Fired Power Plant (OFPP) when it is compared with Hydro Power Plant (HPP)?

Q10. How important/preferable is Nuclear Power Plant (NPP) when it is compared with Hydro Power Plant (HPP)?

With respect to Appropriate Location for Plant (APLOC)		Importance (or Preference) of one method over another											
		Attributes of LHS is					MIDDLE	Attributes of RHS is					
Questions	Attributes	Absolutely More	Very Strongly	Strongly More	Weakly More	Equally Important	*Just Equal*	Equally Important	Weakly More	Strongly More	Very Strongly	Absolutely More	Attributes
		than attributes of RHS						than attributes of LHS					
Q1	GFPP												CFPP
Q2	GFPP												OFPP
Q3	GFPP												NPP
Q4	GFPP												HPP
Q5	CFPP												OFPP
Q6	CFPP												NPP
Q7	CFPP												HPP
Q8	OFPP												NPP
Q9	OFPP												HPP
Q10	NPP												HPP