User Friendly Package for Ranking of Technology Alternatives using Analytical Hierarchy Process

B.Tech. Project Stage-I Report

Submitted in the partial fulfilment of the requirement for the degree of

Bachelor of Technology in Mechanical Engineering

by

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Declaration

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Shantanu Mahajan

14th November, 2008

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Acceptance Certificate

The project report entitled User friendly package for ranking of technology alternatives using Analytical Hierarchy Process (AHP) by Shantanu Mahajan, Roll No: 05010019, under the guidance of Prof. A.W.Date, and Prof. Ganesh Ramakrishnan submitted in partial fulfilment of the requirements for the degree of **Bachelor of Technology** may be accepted for evaluation.

Signature of the Guide: **Date:** November 14, 2008.

Place: *IIT Bombay, Mumbai.*

Date:

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Abstract

Earlier studies of few authors [1,2] have shown the choice 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 social, in addition to the techno-economic factors. This leads to a multi criteria decision making. Studies on choice of technology are aimed at discovering the development-promoting potential of a specific technology which requires a holistic description of alternative technologies through a unified set of attributes; followed by a ranking of alternatives within a given development perspective. The problem of choice of technology is viewed as a technology-ranking problem taking into account that we are choosing from multiple technology options available at hand. It can be shown that choice of technology is influenced by development perspective. The **Analytic Hierarchy Process (AHP)** which is based on mathematics and human psychology is a structured technique for helping people deal with complex decision. Rather than prescribing a "correct" decision, the AHP helps people to determine one [3]

The aim of this project is to build user friendly software package using AHP which will enable the user to decide the best option available as per his needs. This Package will enable the user to see the technologies ranked and also the consistency index.

1.Introduction

Appropriate technology is defined as any object, process, ideas, or practice that enhances human fulfilment through satisfaction of human needs [4]. **Appropriate technology** (AT) is also defined as technology that is designed with special consideration to the environmental, ethical, cultural, social and economical aspects of the community it is intended for [5]. With these goals in mind, AT typically requires fewer resources, is easier to maintain, and has a lower overall cost and less of an impact on the environment compared to industrialized practices. Due to the presence of organizational and institutional barriers, it is not uncommon to see that appropriate technologies cannot be promoted in the developing countries [6,7,8]. And as globalisation strategies gain importance there is a fear that the indirect relationship between technology and socioeconomic policies may be turned into divorce [1]. The package that is being developed under this project is an aid in understanding the information available about the various technology alternatives and to choose the right technology. The package is able to rank the technologies from best to worst and also quantify how much best the best alternative is.

A study [1] shows the effect of development perspective of the decision makers has a strong influence on the choice of technology. This Package can be used to show it. It will do all the needful calculations on input given by user, be it decision maker or an entrepreneur making his plans. The can find its use in making a decision like whether to put up a mass production plant or to come up with many small plants across the country.

If the technologies are described through unified set of criteria (which are both quantitative and qualitative) so that impacts of alternatives in several directions can be assessed, using AHP ranking of technologies can be done. Section 2 describes advantages of using AHP and also how it works. There are not many studies on the characterization of technology alternatives based on techno-socio-economic factors relevant for judging their appropriateness. Section2 lists of some them. This package can be used to rank those technologies.

The Package is able to do a sensitivity analysis of the ranking done based on the attributes under consideration. This is to help with the situation where user is not sure of the data he is giving as input.

So to conclude with, the problem definition is: to build a user friendly software package which will rank the technological alternatives. The motive is to help one choosing the alternative which can be a fairly complex decision.

2.Analytic Hierarchy Process (AHP)

AHP is a systematic method for comparing a list of objectives or alternatives. When used in the systems engineering process, AHP can be a powerful tool for comparing alternative design concepts [9]. AHP is based on mathematics and human psychology. It is a structured technique for helping people deal with complex decision. Rather than prescribing a "correct" decision, the AHP helps people to determine one. It can convert qualitative attributes into quantitative ones. AHP provides a pair wise comparison method for arriving at the weights and also measure for consistency of pair wise comparisons. Another advantage of it is in structuring a decision problem into a number of hierarchical levels. In multi-criteria decision making, AHP has been used at several places. Zehadi [10] and Vargas [11] have provided good reviews of the applications of this method available in literature.

Date [12] has done characterization of technology alternatives in four technologies: namely soap-making, vegetable oil extraction, leather tanning, and water purification. Baron [13] has presented case studies on the choice of technologies in 11 food-processing industries with reference to their appropriateness for third world countries. Karmarkar [14,15,16] has characterized the alternatives in cement making, brick making, and rice milling. In [1], detailed solved problem of ranking of technologies for soap making is given. That problem is solved by AHP. The same paper also has sensitivity analysis, in which the ranking is again done ignoring one-one major criterion each time. The package will be able to do the same. The project is entirely based on making software that will do calculations that are shown in [1].

The package will take various inputs from user as what is the objective of user or main goal. What are the different alternatives that are available with him? What will be the scale of the production such as large scale, medium scale? Then user will be asked to enter the number of qualitative attributes and quantitative attributes and a bit of description. User would then quantify the quantitative attributes and will give input about qualitative attributes. From process to process and from goal to goal these will vary but more or less time to set up the plant, capacity of the plant, capital requirement, energy requirement, raw material, waste disposal and manpower needed will be common in each case.

Based on whether a quantitative attribute is a benefit or cost to the user, it will be normalised for each technological alternative. For example, in the problem of choosing a car from available models, if cars A,B,C,D... have a,b,c,d... as their respective MPG (miles per gallon) ratings, they can be normalised as

$$\text{Normalised value for a} = \frac{a - \min(a,b,c,d\ldots)}{\max(a,b,c,d\ldots) - \min(a,b,c,d..)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Similarly, if a,b,c,d... are their costs

Normalised value for a $= \frac{\max(a,b,c,d\ldots)-a}{\max(a,b,c,d\ldots)-\min(a,b,c,d..)}$ 2

User therefore will be asked whether an attribute is a cost or benefit from his perspective.

AHP gives user a facility to compare different attribute with each other. User will be asked to make a pair wise comparison between alternatives. A matrix of such pair wise comparison thus formed by user will be used to show user how much consistent he comparison was. For example, if user likes mangos twice as much as bananas and bananas thrice as much as apples then normally he should give input for comparison between mangos and apples as mangos preferred six time as much as apples. This is called consistency. Normally, little inconstancy in the judgements is allowed (say, 15%).

$$CI= (\lambda_{max} - n)/(n - 1) \leq 0.15 \quad \text{.....3}$$

Where CI is consistency index, n is number of attributes compared and λ_{max} is maximum eigen value for comparison matrix.

The greatest eigen value of comparison matrix is found out and corresponding eigen vector is normalised by dividing each of its elements by sum of all elements. This vector is called the priority vector which determines the weight of the attributes. Pair wise comparisons of the alternatives with respect to each qualitative attribute are done by user himself with the help of his inputs.

User will have to make judgements like how many times something is preferred over the other. In this, due to lack of expertise, not every time we can expect a correct judgement. So, a sensitivity analysis is done by eliminating one-one major criteria and ranking the technologies again. This will help in making final judgement.
Ranking is done by AHP's equation given by

$$R_j = \sum_{i=1}^{n} (p_{ij} w_i)$$

.....4

Where R_j is rank of *jth* alternative p_{ij} is the normalised attribute value of the *jth* technological alternative with respect to the *ith* attribute. And w_i is the weight of the *ith* attribute.

The Graphs will be plotted which will show the ranking of technologies.

AHP Example solved

Consider a problem of choosing a best car amongst the available options viz., Accord Sedan, Accord Hybrid, Pilot SUV, CR-V SUV, Element SUV, Odyssey Minivan.

Criteria under which the options are evaluated can be: Purchase cost, Maintenance Cost, Fuel Cost, and Capacity.

A linear scale of 1 to 9 is used to determine the relative importance of attributes. For example, if a person says attribute A is "moderately more important" than attribute B, A is said to have a relative weight of 3 times that of B while being "extremely more important" will give A a weight of 9 times that of B.

User is asked to do a pair wise comparison. Purchase cost is compared with all other criteria. Suppose, user thinks, for him, it is three times more important than Maintenance cost, Fuel cost, and then he will enter 3 in the first row in those columns. And so on till he finishes the entries.

The lower triangle in the matrix will be automatically generated as the inverse of the user's entry. Main diagonal will also be automatically come as 1 in the package.

When these *attributes* are compared against each other, a comparison matrix is formed. Table 1 shows that matrix.

Table 1

Attributes	Purchase cost	Maintenance Cost	Fuel Cost	Capacity
Purchase cost	1	3	3	9
Maintenance Cost	1/3	1	1/3	9
Fuel Cost	1/3	3	1	5
Capacity	1/9	1/9	1/5	1

Greatest eigen value of the matrix formed is 4.358. And corresponding *normalised* eigen vector is

$(0.508 \quad 0.182 \quad 0.271 \quad 0.039)^T$.

This is a priority vector. Priority given to attribute Purchase cost is 0.508 or 50.8%.

The consistency index is 0.119 which is low enough.

User will also provide the data available with him, which is shown in table 2.

Table 2: Characteristics of the alternatives

	Accord Sedan	Accord Hybrid	Pilot SUV	CR-V SUV	Element SUV	Odyssey Minivan
Purchase Cost	1018000	1554500	1379750	1035000	949000	1282250
Maintenance Cost*	700	700	1400	1600	1730	2000
Fuel Cost**	31	35	22	27	25	26
Capacity	5	5	8	5	4	8

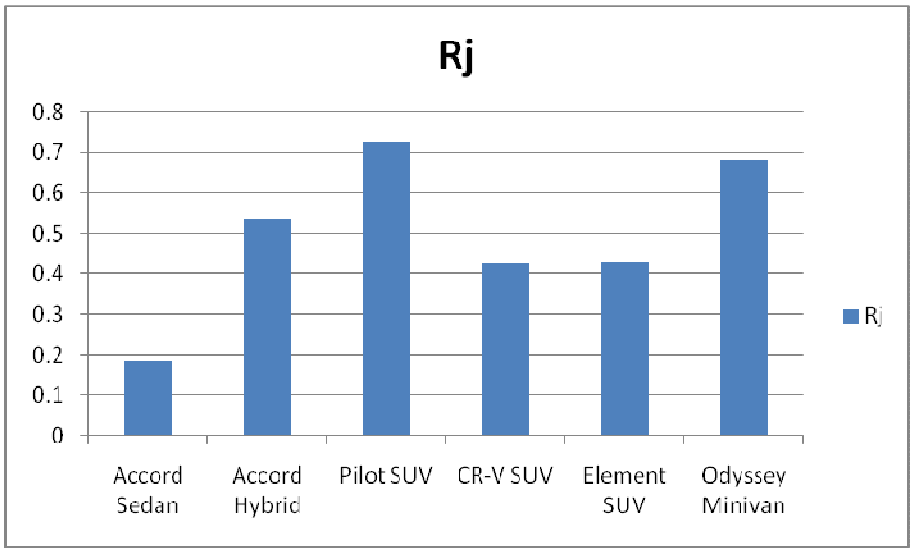
*data based on Wikipedia website.

** Expressed in terms of MPG (Miles Per gallon)

The user has following impressions about the attributes. Purchase cost and Maintenance cost : lower the better and Fuel Cost and capacity : Higher the better. With the help of equations 1 and 2 this translates into table 3. It has rankings calculated by equation 4 and the values and the table 3.

Table 3: Final Attribute Weights and Normalised Attribute Matrix with rankings.

	Accord Sedan	Accord Hybrid	Pilot SUV	CR-V SUV	Element SUV	Odyssey Minivan	Priority Vector
Purchase Cost	0.114	1	0.711	0.142	0.001	0.55	0.508
Maintenance Cost	0.001	0.001	0.538	0.692	0.792	1	0.182
Fuel Cost	0.364	0.001	1	0.727	0.909	0.818	0.271
Capacity	0.75	0.75	0.001	0.75	1	0.001	0.039
Rj	0.186	0.537	0.73	0.424	0.43	0.683	
Ranking	**6**	**3**	**1**	**5**	**4**	**2**	



3.Work Plan

The package has to do Matrix algebra. And considering the ubiquity of the client a web-app is a good option. So we decided to build a web-app.

August	Understanding AHP, the Problem Definition
September	Surveying for available packages, similar algorithms, codes, etc.
October	Finalising the software technology to be used. Gathering resources like tutorials, Installation of Free software in Computational Lab.
November	Developing UIs, jsp

The status of the work for August, September, October, and November is as follows:

First, AHP is understood. Secondly, the problem is well defined.

Surveying for code gave few results like .Net package [17], web pages [18] which did little bit of AHP calculations, but no full length code is available even in .Net or any other language. Similar codes for Principal Component Analysis [19], Multi-Dimensional Scaling [20] were studied. Scilab®, free software was chosen instead of MATLAB®. The front ends will be developed using html forms with JSPs (Java Server Pages) and the back-end will be developed as a Java servlet that will access the Scilab API.(It has Java API [21]). Online tutorials (majorly from www.w3school.com) for html, jsp, Apache TOMCAT, Scilab were studied (and are still being studied). Simultaneous working on code is going on. Few of the UIs are ready and others will be, as the code for those pages develops while the software like Scilab, Tomcat are being installed in Department Computational Lab.

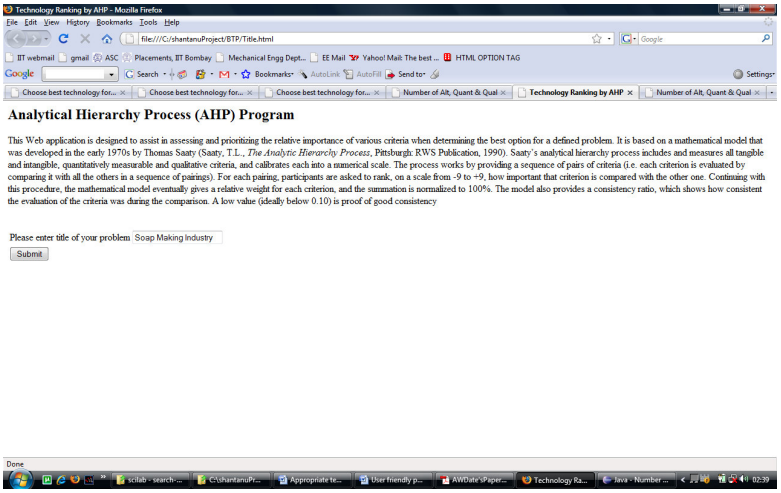
Future work will be

December	Coding
January	Coding continued
February	Coding to be completed
March	Testing, Debugging, Finishing.

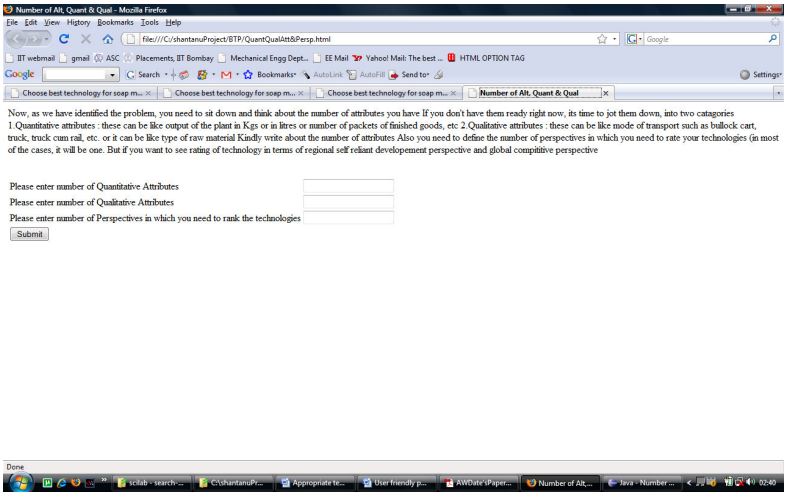
4. Snapshots of the tool in progress

The tool that we are developing is in primary stage. Few of the UIs that are formed are shown below. First of all we will ask user the title of his problem or his goal. He will then need to enter the number of qualitative and quantitative attributes, then their names, and whether they mean cost or benefit to him. He will need to make pair wise comparisons between the attributes.

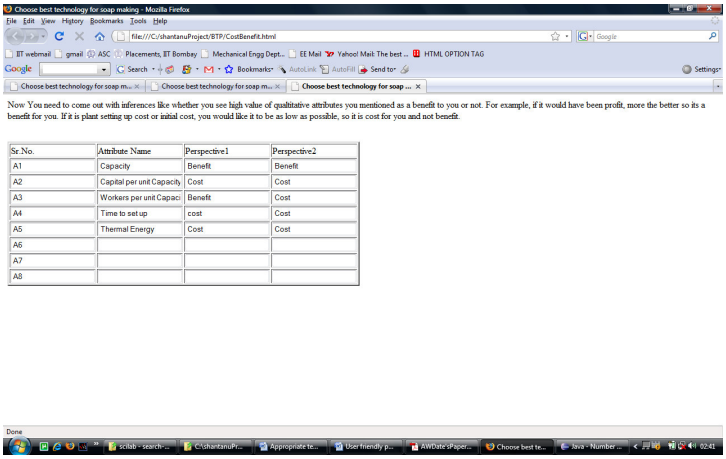
1.Front Page.



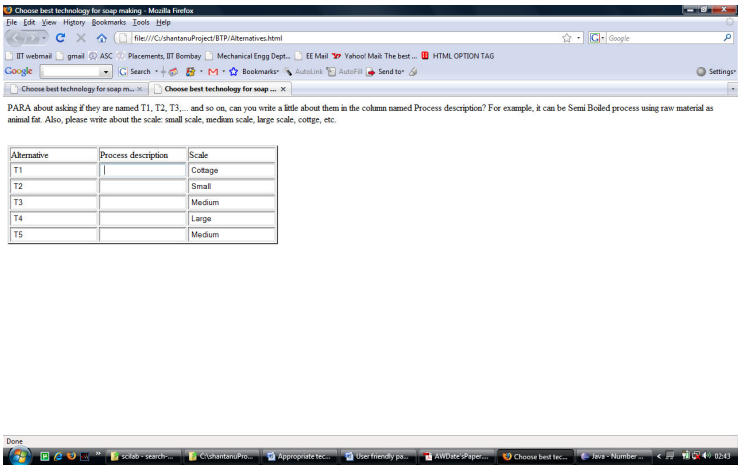
2.Page where user will give inputs like number of Qualitative and Quantitative Attributes.



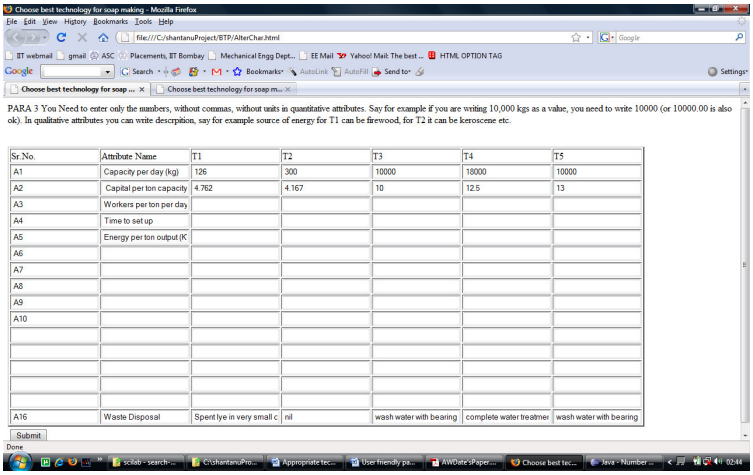
3. Table where user will be entering attribute names and whether they qualify as benefit or cost.



4. One more table to filled up by user to define the technological alternatives.



5. Page where quantifying of attributes is to be done and qualitative attributes are to be entered



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