# Multi Attribute Utility Theory – An Over View

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**Abstract :** This paper describes the evaluation of the Multi Attribute Utility Theory(MAUT), one of the Multi Criteria Decision Making(MCDM) techniques. It was introduced by Fishburn (1965,1970), Keeney(1969,1971,1973), and Raiffa(1969) who proposed a decision making technique designed for taking decisions under risk. This paper also explains how the theories, concepts and ideas of MAUT help an individual in rational decision making, how an individual is easily able to understand the basic concepts of the above said method, how the data are quantified, how far it is effective in making decisions for solving a problem in the real time situation, besides discussing how the judgement and uncertainities can be considered in the Multi Criteria Decision Making Method(MCDM). This method handles the problem of making a decision in different logical and meaningful manners. In a case study , it was demonstrated how the method could be used in making a decision under uncertainty. Also in this paper is illustrated how a decision becomes good when the decision maker is a computer science teacher who chooses his computer for his personal work and how it helps him in his personal life. We can conclude that MCDM methods do consider uncertainty . The different sections are 1. Introduction, 2. Algorithm of MAUT, 3. Problem representation, 4. Essential Components of a Computer, 5. Recent Technology , 6. MAUT – Process, 7. Results & Discussion, 8. AHP vs MAUT , 9. Conclusion , and 10. References.

**Significance :** In many individual decisions the final choice depends on the evaluation of a set of alternatives in terms of the number of decision criteria and the final solution is based on the domain knowledge of the decision maker's expertise, because the decision maker knows the value of the criteria, and has the knowledge of the alternatives used. The MAUT facilitates an effective way for properly quantifying the applicable data.

**Keywords :** Multi-Criteria Decision-Making(MCDM), Multi Attribute Utility Theory (MAUT), Uncertainty.



## 1 INTRODUCTION

This paper considers a particular example of how an individual chooses a computer for his personal work when the individual is a computer science Teacher who wishes to select a recent configuration computer system with respect to his budget, using MAUT as the decision making method. This theory has been used by many researchers. This problem can be represented as a tree shaped structure with goal , criteria & sub-criteria etc. The qualities mostly required for choosing a computer can be declared as the number of criteria, based on the evaluation of a number of alternatives. The MAUT is an effective MCDM approach in dealing with this kind of decision making problems. This is a normative approach (i.e) based on how to value the entity, which entities are good or bad. But there is no descriptive and subjective bases asserted in this theory. This paper deals with some of the practical and computational issues involved, when the MAUT method is used in solving individual decision making and shows how the decision should be taken. The probabilistic weights are allocated for the importance of the decision criteria by a decision maker based on his requirements and past experiences or his own expertise. It suggests how a decision maker should select a product according to his requirement. Here, the criteria used are the speed, easily upgradable, and the cost. The speed of the computer is based on the performance of the RAM(Random Access Memory) and the processor. Therefore, the RAM(primary memory) and the performance of the processor are the sub criteria of the criterion 'Speed'. The Criterion 'easily upgradable' is possible only for assembled system while for 'Branded one' only a few RAM slots are available to upgrade. 'Cost' is the another important criterion which is based on the Decision Maker's personal interest.

## 2 ALGORITHM OF MAUT

This algorithm has the following steps :

Step-1 : Use Utility functions to convert numerical attribute scales into a utility unit scale.

Step-2 : Assign weights to the attributes and then calculate the weighted average of each end result set as an overall utility score.

Step-3 : Compare utilities using the overall utility score.The Utility quantifies the degree of fulfillment of an outcome and for n possible outcomes $X_1, X_2, X_3 \ldots\ldots\ldots X_n$, the expected utility is

$$EU = \sum_{i=1}^{n} p(X_i) \times U_i(X_i) \quad \text{---------- (1)}$$

The same formula for the Expected Utility theory (EU) is then modified to form

$$U(X) = \sum_{i=1}^{n} w_i \times u_i(x_i) \quad \text{with} \quad \sum w_i = 1 \text{ ----------(2)}$$

From this formula (equation-2)the probabilities are replaced by the importance weights involving the criteria. The formula for the expected utility is used, and utility functions are used to express the desirability of the attributes. The overall utility of an alternative with a number of criteria is defined by the following additive function shown in equation –(2).

## 3 PROBLEM REPRESENTATION

The Multi-Attribute Utility Theory becomes a suitable decision-making method when the decision maker has to take several requirements into account. It is a normative method because it notifies what we should do. Here the probabilities(p(X)) are judged by the decision maker based on his own experience. For all decision making processes, the domain person will interact with the decision maker to analyse the problem or a decision maker who is responsible to analyze a problem. The MAUT has the advantage of permitting a hierarchical tree shaped structure of criteria (Figure -1), which enables the users to focus on specific criteria when allocating the weights. This procedure is significant because a different structure may lead to a different outcome.

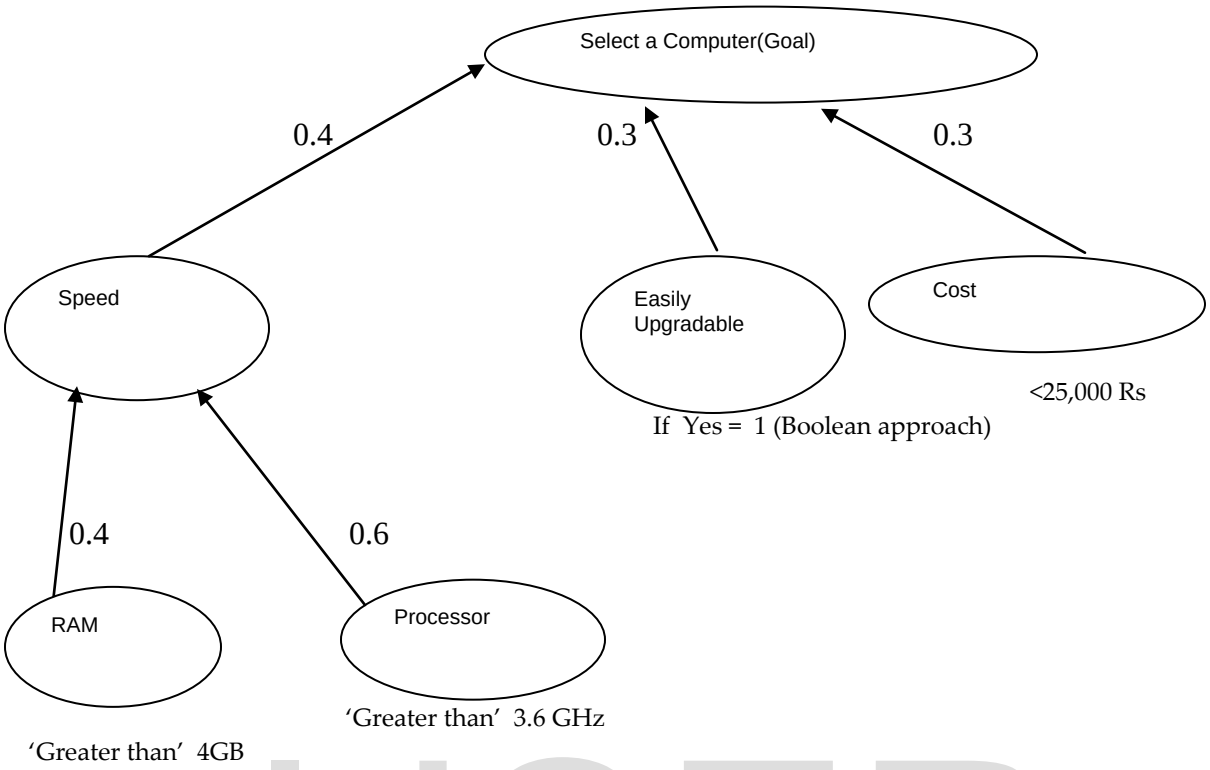


Figure – 1 Criteria Tree with Weights assigned to required measurements



## 4 ESSENTIAL COMPONENTS OF A COMPUTER

Processor with suitable Motherboard, RAM(Primary Memory),Harddisk(Secondary Memory), Input devices such as Keyboard & Mouse, Output devices such as Monitor, Speakers, Optical Drive, Power Supply (SMPS) & Cabinet etc. But the main elements taken into account are Processor and RAM , the rest of the other components being common for all the computers. But in normal configuration of a computer Harddisk (Secondary memory)space is greater than 160 GB with display unit Montior being LCD or LED that is used for latest configuration for space convenience and reducing the energy consumption, because the main energy consuming element is a Monitor. The major concentration is only on RAM and Processor.

## 5 RECENT TECHNOLOGY

All the way through time, manufacturers of the microprocessor have developed a certain number of improvements that optimize processor performance. Parallel processing, Pipelining, Super Scalar architecture, Hyper Threading & Turbo boost are the technologies evolved in the recent technological improvements. Parallel processing consists of concurrent execution of instruction from the same program on different processors. This involves isolating a program into multiple processes handled in parallel in order to reduce execution time. The goal of the Pipelining is fetching, decoding and execution of the instruction in parallel to improve the efficiency of the processor. Superscalar architecture consists of placing multiple processing units in parallel in order to process multiple instructions per clock cycle. HyperThreading consists of placing two

logic processors connected with a physical processor; then the system identifies two physical processors and behaves like a multitasking system by sending two simultaneous threads. Turbo boost technique automatically turns cores on and off as required. If a machine is running a quad-core processor but only one core is required, three of the cores will be shut down to save power or to redirect some of their power to the one working core. The sleeping cores will automatically power up when required. Intel's core i3 ,i5 & i7 are the recent processors. Core i3 is a low end processor having hyper threading with no turbo boost technology implemented. Core i5 (mid level processor) & i7(high end) have both hyper threading and turbo boost technology implemented in dual and quad core processors for desktop & laptops.

RAM Specifications : DDR SDRAM (Double Data Rate Synchronous Dynamic Random Access Memory) called DDR or DDR-1 has been superseded by DDR2 and DDR3, either of which will not work in DDR – equipped motherboards. DDR2, DDR3 can vary in internal clock speeds. The name "double data rate" refers to the fact that a DDR SDRAM with a certain clock frequency achieves nearly twice the bandwidth of an SDR SDRAM (Single Data Rate) running at the same clock frequency, due to this double effort. For example, with data being transferred 32 bits at a time, DDR SDRAM gives a transfer rate of (clock rate of the memory bus ) × 2 × 32 (number of bits transferred) / 8 (number of bits/byte). Thus, with a bus frequency of 200 MHz, DDR SDRAM gives a maximum transfer rate of 1600 Mega Bits/sec.

## 6 MAUT – PROCESS

Consider a real time scenario : A Decision Maker wishes to buy a new configuration system and focuses attention on the speed aspect of the computer, its cost and its easily upgradability. The cost of the computer should be less than 25,000 Rs. The computer should be easily upgradable in future; normally majority of the assembled systems are easily upgradable, the performance (speed) of the computer being based on processor performance greater than 3.6 GHz and primary memory (RAM) greater than or equal to 4GB.

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Data Set :

| Computer -1 (Assembled) | | |
|---|---|---|
| Processor | AMD FX4100 – 3.6GHz (4 Core) | 6,750.00 Rs |
| Motherboard | Asus 760G M5 A78L-M LE | 3,250.00 Rs |
| Memory | Corsair 4 GB DDR3 1333 MHz | 1,250.00 Rs |
| Harddisk | Seagate 500 GB | 3,850.00 Rs |
| Keyboard | Logitech Multimedia | 400.00 Rs |
| Mouse | Logitech | 325.00 Rs |
| Speakers | Creative Inspire 2.1 T 3130 | 450.00 Rs |
| Optical Drive | Samsung DVD Writer | 950.00 Rs |
| PowerSupply | Zebronics 500 W | 2,000.00 Rs |
| Monitor | LG 20" -2043 C | 5,400.00 Rs |
| Cabinet | Zebronics Mid Range | 1,000.00 Rs |
| Total | | 25,625.00 Rs |

| Computer -2 (Assembled) | | |
|---|---|---|
| Processor | AMD Phenom III Quad X4 840 3.2GHz (4 Core) | 5,000.00 Rs |

| | | |
|---|---|---|
| Motherboard | Gigabyte GA – M68 MT – S2 | 2,350.00 Rs |
| Memory | Transcend 4GB 133 MHz DDR3 | 1,800.00 Rs |
| Harddisk | Seagate 500 GB | 3,850.00 Rs |
| Keyboard | Logitech Multimedia | 400.00 Rs |
| Mouse | Logitech | 325.00 Rs |
| Speakers | Creative Inspire 2.1 T 3130 | 450.00 Rs |
| Optical Drive | Samsung DVD Writer | 950.00 Rs |
| PowerSupply | Zebronics 500 W platinum | 1,850.00 Rs |
| Monitor | Dell LED 20″ – IN 2020M | 6,650.00 Rs |
| Cabinet | Zebronics Butterfly | 1,250.00 Rs |
| Total | | 24,875.00 Rs |

| Computer – 3 (Branded) | |
|---|---|
| Name | HP Compaq Pro 6305 Business PC |
| Processor | AMD A – series Quad – Core (A10 5800 B,A8 – 5500B) (4 Core) |
| Chipset | AMD A75 |
| Memory | 1600 MHz non – ECC DDR3 SDRAM (4) DIMM slots enabling upto 32 GB |
| Internal Storage | A full range of harddisk and solid state storage drives including some with self-encrypting capabilities. |
| Removable Storage | Optional disk drives & a media card reader supporting data storage and backup, multimedia and software installation. |
| Cost of the Computer = 48,000 Rs | |



| Computer -4 (Assembled) | | |
|---|---|---|
| Processor | AMD Phenom II X4 955 3.2GHz (4 Core) | 6,000.00 Rs |
| Motherboard | ASUS M4A88T – M-LE | 3,500.00 Rs |
| Memory | 4GB DDR3 RAM | 1,300.00 Rs |
| Harddisk | Seagate 500 GB, SATA | 3,850.00 Rs |
| Keyboard | Logitech Multimedia | 400.00 Rs |
| Mouse | Logitech optical Mouse | 325.00 Rs |
| Speakers | Creative Inspire 5.1 | 450.00 Rs |
| Optical Drive | Samsung DVD Writer | 950.00 Rs |
| Monitor | 22″ TFT Monitor Samsung | 7,500.00 Rs |
| Cabinet | Cooler Master ATX Cabinet(with Cooler Master 450 Watts SMPS) | 1,725.00 Rs |
| Total | | 26,000.00Rs |

Figure -1 shows that the Criteria Tree has four leaf nodes; from this consideration ,for Computer -1, the first leaf node, the Primary Memory (RAM) of the processor which is greater than or equal to 4.0 GB will be taken as the linear increasing function, with the values using between 2.0 GB and 4.0 GB and getting utilities between 0 and 1. The MAUT uses the fuzzy logic approach,

$U(x) = (X - X_{i\,(\text{lower bound})}) / (X_{i\,(\text{upper bound})} - X_{i\,(\text{lower bound})})$

For RAM, U(x) = ( 4 GB – 2GB) / ( 4 GB – 2GB) = 1. The second leaf node, the frequency of the processor which is greater than or equal to 3.6 GHz, will be taken as the linear increasing function, with the values using between 1.8 GHz and 3.6 GHz and getting utilities between 0 and 1. For Processor, U(x) = (3.6 GHz– 1.8 GHz)/ (3.6 GHz– 1.8 GHz) = 1. Then the criterion, Speed of the computer, can be determined according to criteria weights assigned as
Speed = 0.4 x (1) + 0.6 x (1) = 1.The third leaf node is the criterion 'Easily Upgradable'. If the computer is easily upgradable in the future, if logically yes, then the the utility function U(x) =1; otherwise U(x) = 0. Normally assembled configuration shown in the following table Computer –1, Computer -2 and Computer -4 have a utility function, U(x) = 1; considering branded configuration , Computer -3 has a utility function, U(x) = 0. The fourth node is the criterion ' Cost'. The computer with a price of greater than 25,000 Rs will have a utility of 0 with respect to the cost criterion and the price less than 25,000 Rs will have a utility of 1. By applying fuzzy logic approach , the utility function for Computer-1 , U(x) is calculated as U(x) = (625 – 12500)/(25000 – 12500)= 0 .95 (absolute value), because the price of Computer-1 is 25,625 Rs and according to the decision maker it is 625 Rs more than the fixed amount. Therefore , the goal =0.4 x+ 0.3 x (1) + 0.3 x (0.95) , (ie) the goal = 0.4 x (Speed) + 0.3 x (Easily Upgradable) + 0.3 x (Cost).

| | **Computer-1** | **Computer-2** | **Computer-3** | **Computer-4** |
|---|---|---|---|---|
| **RAM** | 1 | 1 | 1 | 1 |
| **Processor** | 1 | 0.78 | 1 | 0.78 |
| **Speed** | 0.4 x (1) +0.6 x (1) =1 | 0.4 x (1) +0.6 x (0.78) = 0.868 | 0.4 x (1) +0.6 x (1) = 1 | 0.4 x (1) +0.6x(0.78)= 0.868 |
| **Easily Upgradable** | 1 | 1 | 0 | 1 |
| **Cost** | 0.95 | 1 | 0.84 | 0.92 |
| **Select a Computer** | 0.4x1+0.3x1 +0.3x0.95 =0.985 | 0.4 x0.868 +0.3x1 + 0.3 x 1=0.947 | 0.4 x1+0.3x0 +0.3x0.84= 0.652 | 0.4 x0.868 +0.3x1 +0.3 x 0.92=0.923 |

## 7 RESULTS & DISCUSSION

From this observation, Computer-1 ranks -1 followed by computer-2, then by Computer-4 and then by Computer-3. The MAUT, one of the Multi Criteria Decision Making methods (MCDM) which uses Weighted Sum Model (WSM) is the best known and the simplest MCDM method for evaluating a number of alternatives in terms of a number of decision criteria. It is very important to state here that this technique is applicable only when all the data are expressed in exactly the same unit, whereas in AHP (Analytical Hierarchy Process), the other MCDM technique, it becomes applicable when the data are expressed in different units. In the AHP, the data are derived by using pair wise comparisons, and there will be a chance of human error; this method is highly sensitive. So the decision maker is very careful in using this method. But the MAUT uses a fuzzy logic approach and the input data are derived from the data available in the data set. Compared with an AHP technique, if an identical copy of an alternative is added or deleted , in this scenario, rank reversal doesn't exist. Based on the data the outcome will be derived. So there is less possibility of getting a human error. But the decision maker clearly knows how to use this method. Any

academic person can use the AHP in an easy manner. So, every decision making method has its own strengths and limitations. Each and every decision will be based on the data and the decision maker.

## 8 AHP vs MAUT

The following tabular column differentiates AHP from MAUT – MCDM method

| Sl No | MAUT | AHP |
|---|---|---|
| 1 | Allows more number of independent criteria | Allows less number of independent criteria, otherwise causes inaccuracy in judgement |
| 2 | Allows more number of alternatives, which are expressed in same measurements | Allows less number of alternatives, which are expressed in different measurements. |
| 3 | Less sensitive | More sensitive |
| 4 | Risks and uncertainty are considered | Risks and uncertainty are not considered |
| 5 | Probabilities are considered as the weights of the decision criteria | Weights of the criteria are derived by pairwise comparison using Eigen value method. |
| 6 | Fuzzy logic approach is used to prioritize the alternatives | Eigen value method is used to prioritize the alternatives |
| 7 | WSM(Weighted Sum Model) is used for calculating the global priority | WSM(Weighted Sum Model) is used for calculating the global priority |
| 8 | Final result will be based on the quantification of the data and the decision maker's expertise | Final result will be based on the decision maker's expertise |
| 9 | This method is purely based on Normative approach. i.e., how to value an item; there is no concept behind in that. | This method is purely based on descriptive and subjective approach. i.e., based on concept derived by an individual , his past experience and his prediction (prejudiced judgement) |

## 8 CONCLUSION

The MAUT is one of the Multicriteria Decision Making methods (MCDM) and it can be successfully applied in different fields. The decision making is based on the past experience of the decision maker; each decision maker has different strengths, intelligence , expertise, thinking, different assessments, mentality, and logical behaviour. The domain expertise of the decision maker is needed in making decisions when using the MAUT; apart from that s/he must have a knowledge of the criteria , the value of an alternative available in the data set and the decision maker must understand the concept of MAUT. Then MAUT becomes a successful decision making method. But in unavoidable circumstences, human commonsense is required to identify and solve complex problems, because humans can process unstructured information [1]. Thus MAUT becomes one of the decision making techniques, an alternative solution to the AHP. According to Robert L.Winkler(1990), the alternative for AHP is the Utility theory, but Utility theory is not the final solution . The decision maker must be alert in accepting the theory[14], and it is based on the decision maker's expertise, because based on the problem the

decision maker can select the MCDM method. Considering MAUT and AHP, if the alternatives are in the same measurement, then ,the decision maker can use MAUT or AHP . But if the alternatives are in different measurements, then, s/he must use only AHP. But each and every method has its major strengths and limitations. So, which MCDM is the best available in practice, is still under discussion. Comparing AHP with MAUT, it can be stated that while AHP does not consider uncertainty, MAUT considers uncertainty[7]. This is a very significant and absorbing issue in decision analysis, and further more, research is required in this field to overcome the drawbacks and limitations of the method.

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