Multi Attribute Utility Theory (MAUT) Driven New Product Development Using Multi Criteria Decision Making (MCDM)

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Abstract

Today's product domain includes an incredible range of brands and models with a highly complex set of features. The project describes issues that support product discovery and selection in domains that include a variety of alternatives that include a complex set of features. Some online shopping sites use the Multi Attribute Utility Theory (MAUT) directly to provide product selection assistance. The MAUT approach is attractive because of its solid theoretical foundation, but there are several reasons why it is not appropriate for people's decision making.

Keywords - *Multi Criteria Decision Making (MCDM), Multi Attribute Utility Theory*

I. INTRODUCTION

Such decisions include comparing alternatives with strengths or weaknesses to the multiple objectives of policy makers. The utility of various features (MAUT, for the acronym in English) is a structured methodology designed to address the obligations between different goals. One of the first MAUT applications concerns the investigation into alternative locations for a New Mexico City airport in the early 1970s. The factors considered are cost, capacity, and access time to airport, safety, social disruption and noise.

The theory of utility is a systematic approach to quantifying the preferences of an individual. It is used to slightly change the size of a numeric value on a scale from 0 to 1, with 0 indicating the worst preference and 1 best. This makes it possible to compare many different measurements directly. It is with the right tools it is really possible to compare apples with pears. The end result is an evaluation of the classification of alternatives that reflects the preferences of policy makers. A similar situation occurs when people, university teams, MBA courses or even hospitals are classified in terms of their performance in different individual measures. Another example is the Bowl Coalition Series (BCS) in college football that tries to identify the two best college teams in the United States to play in a championship match. This process reduced the arguments about which school to become national champion at the end of the year.

MAUT's first applications are aimed at public sector decisions and public policy issues. Not only do these decisions have many goals, but they also involve different groups that are affected in different ways. Under the leadership of Ralph Keeney, a leading field researcher, many power station decisions were made using MAUT.

II. LITERATURE REVIEW

Most traditional tools for cost modeling, reasoning and calculation are sharp, deterministic and of a precise nature. Many parameters are uncertain in the real production environment. The parameters of the model are not definitively known in the early stages of the design. That is why there is a need for a cost estimate model to combat this shortcut. To estimate costs accurately, designers must develop techniques that reduce inherent inaccuracies and subjectivity, and can resolve these problems in the cost estimation process (Ting et al., 1999).

According to Keeny and Raiffa (1976), MAUT is a series of systematic procedures designed to quantify a person's preferences. With these characters, Ting et al. (1999) constructed for the first time a cost estimation model using the theory of the utility of multiple attributes, which also combines historical data to avoid objective assessments.

Similarly, Dong et al. (2003) constructed an MAUT cost estimation model that combines fuzzy theory to combat uncertainty in nature and the information associated with each cost factor can be qualitative.

Through the Multiple Attribute Utility Theory for the cost estimation model, the costs are identified as accurately as possible and as objective as possible to provide information about the decision to the decision maker. It is more effective than traditional methods because it does not require detailed information (Dong et al., 2003).

Multi-Attribute Utility Methodology and Techniques

To overcome the difficulty of estimating costs in the initial phase of the design, the MAUT model is used in this study to estimate the costs. Based on Ting et al. (1999) and Dong et al. (2003), the costs are estimated using the following comparisons. The value evaluated by the last comparison is the cost index (CI).

$$U(X) = \prod_{i=1}^{m} \frac{[W \times wi \times Ui(xi)+1]-1}{W} \quad (1)$$

$$1+W = \prod_{i=1}^{m}(1 + W + wi) \quad (2)$$

$$[CI] = Cost\ (X) = ae^{b\,[U(X)]} \quad (3)$$

Where,

- U(X) = Utility value of focus alternatives depending on the level of each attribute
- $X = (x_1, x_2, x_3, x_4 \ldots x_m)$
- W = Scaling Factor
- w_i= Weight for attribute i
- m = Number of attributes
- $U_i(x_i)$ = Utility Value of attribute i at level x_i
- x_i = Specific Level of each attribute i
- Cost (X) = Estimated Cost value depending on each x_i
- a, b = Parameter of regression model
- e = Base of natural logarithm

III. UTILITY FUNCTION TYPE

- Linear utility function: $U_i(x_i) = \frac{xi}{\max (xi)}$
- Convex utility function: $U_i(x_i) = 0.0121e^{4.415\frac{xi}{\max (xi)}}$
- Concave utility function: $U_i(x_i) = -1.324 \left[\frac{xi}{\max (xi)}\right]^2 + 2.29 \left[\frac{xi}{\max (xi)}\right] + 0.053$

The previous model for cost estimation contains two main components. Equation (1) and (2) is to transfer the attribute level to use the value. Equation (3) is the regression model to transfer the use value to the estimate value. To strengthen the applicability of the first stages of design, based on Ting et al. (1999) and Dong et al. (2003), follow the steps adjusted to apply this model.

- ***Identify attribute i (i = 1 …m) that mainly contributes the total cost:***

Beforehand, the main attributes that result in expenditure should be recognized.

- ***Identify the highest level (max x_i) and weight (w_i) for the attribute i:***

After the attributes are recognized, the highest level for attributes i (max xi) is going to be determined by experts. Weight for each attribute (w_i) is given according to the influence of each attribute on the cost.

- ***Construct the utility function for each level of attribute:***

Different from preference-query questions, this research proposed an easier way to derived cost utility function by assigning a specific typical utility function type. These functions as shown in figure namely linear, concave and convex utility function, represents the relationship between attribute levels (x_i) and utility value ($U_i(x_i)$) while comparing the highest level and lowest level. Note that the utility value of the highest level always equates 1. This step is done to obtain the utility value of attribute i at specific level xi ($U_i(x_i)$) with easiness rather than preference-query question that would be more complicated.

- ***Evaluate the utility value of focus alternatives (U(x)):***

This stage is to evaluate the utility value of each alternative with equation (1) and (2) when above steps were done.

- ***Transfer utility value (U(x)) into cost value:***

This stage is to convert the utility value (U(x)) into cost value with the regression of historical data as equation (3). Cost value is obtained through above steps. This estimative value represents an objective. Predict cost considering cost attribute and historical data and is adequate to be cost indicator of focus alternative.

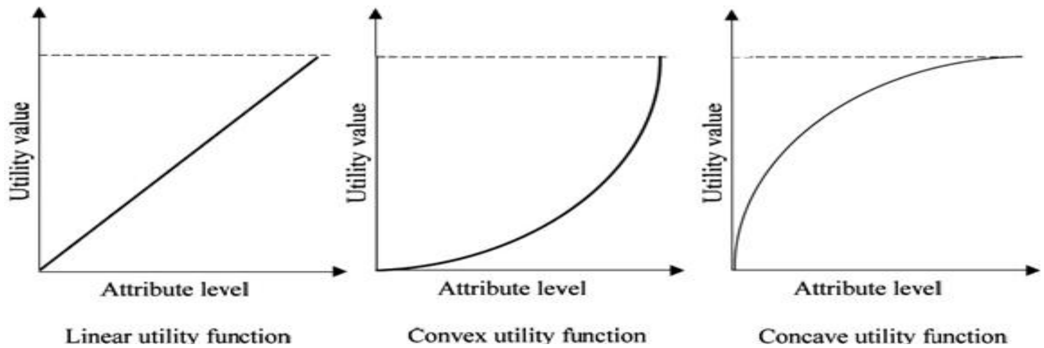

Figure 2.2 Three Typical Utility Functions

Table: Cost Attribute Levels & Related Data

Cost Attribute(i)	**Weight (W_i)**	**Highest Level (x_i)**	**Utility Function**
Complexity for product	0.7	9	Convex
Quality of product	0.9	4	Linear
Material in manufacturing	0.6	5	Linear
Size of product	0.4	3	Linear
Energy Consumption	0.6	3	Linear
Reverse Logistics	0.3	5	Linear

Table:Design for Utility

Cost Attribute(i)	**Design Level (x_i)**	**Utility Value $U_i(x_i)$**
Complexity for product	6	0.23
Quality of product	3	0.75
Material in mfg.	2	0.20
Size of product	2	0.67
Energy Consumption	2	0.67
Reverse Logistics	2	0.40
U(X)	0.8365	

Calculations Value

Now constructing the regression model for which converting the utility value into cost value using equation (3).

$$\text{Cost (CI)} = 3.7487e^{[5.5659 \text{ X } U(x)]}$$

The calculations of estimated cost using regression model are as follows:

$\text{Cost (CI)} = 3.7487e^{[5.5659 \text{ X } U(x)]}$

$= 3.7487e^{[5.5659 \text{ X } 0.8365]}$

$= 3.7487e^{4.6558}$

$= 3.7487 \text{ X } 105.203$

Estimated Cost = 395 Units

IV. RESULT & DISCUSSION

Considering the multiple attributes of the product and various parameters, the product can be developed in various ways and the approximate cost of the product can be estimated.

As per the criteria's considered in this work along with the parameters the Multi Attribute Utility Theory is applied. Where initially the parameters are considered as per our requirement based on various levels. Then Utility value of overall product is calculated which is equal to 0.8356.

Thereafter, the cost index of the designed product is calculated. With the help of cost index, the estimated cost of the designed product is determined which is equal to 395 units.

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