A Expert System for aid in material selection process

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Abstract

An Expert System for aid in material selection process is proposed, which in conjunction with TOPSIS (Technique for Order Preference by Similarity to Ideal Situation) method[1] provides a very effective and efficient technique of material selection for a component. TOPSIS is a highly advanced optimization technique, which requires that user provides relative importance to different properties by the author[2], the relative importance rating were to be decided by the designers. There it was pointed out that the designers may not arrive at the same conclusion due to their different rating technique even though they use the same technique. In the proposed method, an expert system has been presented, which use a small tool called Ruleniaster[2][3], and OPSS (developed at IIT Delhi) that facilitates the development of particular consultant paradigms. In identifying the knowledge base which was to be included in the system, special care was taken so that different designers get uniform results by using the proposed system.

Introduction

Recently an attempt[2] was made to solve material selection problem using MADM (Multi Attribute Decision Making) approach, called TOPSIS. TOPSIS is in fact an improvement on additive weight methods, and actually aims to give us a solution, that is closest to the ideal solution as well as farthest from the negative ideal solution. The method needs information oh relative importance of properties, considered in selection process, with respect to another. This information is sought in terms of a ration and is also represented in a matrix. Material Selection problem is a multi objective optimization problem with some design and manufacture related constraints[4][5][6][7]. The two main objectives, in material selection for a component, are cost reduction and improving functional performance ratings. In the technique which uses TOPSIS, properties of material considered in selection of material for a component, called attribute. As mentioned in the above paragraph, TOPSIS requires that weightage has to be assigned by the designers, to these attributes. Individual designers may differ on assigning these weightages, because they may base their judgement on meeting the two stated objectives in different manner. Because these importance rating affect the final result to a large extent, different designers, may not arrive at same conclusion in material selection even though they use the same technique. In the proposed method simple system of comparison of values of different attributes was provided to designer for helping them in arriving at values of relative importance of attributes.

The system presented in this method was a simple one and here we present it some detail. Suppose two attributes \(a\) and \(b\) are in consideration and are to be assigned the relative importance. In the first step, the designer is asked to generate a curve “Value of attribute vs Cost of materials”. Here typical curves are shown in figure 1.

![Figure 1. Value of attribute vs cost of materials.](image)

Then another curve is to be generated between “Value of attribute, \(a\) vs Value of attribute, \(b\). Figure 2 denoted the relationship amongst these two values.

![Figure 2. attribute \(a\) vs attribute \(b\).](image)

These curves are used to obtain values of relative importance of attributes, which involves analysis of curves to get relevant
information from them. Information is sought on the relation, even approximate, that may exist between attributes and cost of materials or in between attributes themselves. If there is case when curves does not represent any general relation, then designers have to give relative importance value of attribute themselves, without any aid. Curves can be used to represent purposeful information if we can get some relation on how attributes are affected by cost and how attribute value affect themselves. Suppose curve 'a' in Figure 1 is considered. It tells of the component in consideration for which material selection to formed by the designers as per the prime functional objective curve relating attribute to the cost. This information received to see that how much more percent the value of an attribute suppose the curve 'a' in Figure 2 is considered. This curve tells that cost of component is not greatly affected by attribute. Now attributes are affected by cost and how attribute value affect purposeful information if we can get some relation on how when curves does not represent any general relation. Then even approximate, that may exist between attributes and cost of particular problem:

1. If attribute, a is of primary importance and cost is very much affected by attribute, a then attribute, a is given a high relative importance, but still not too high.

2. If attribute, a is of low importance for the component in consideration and curves provide us information that value of attribute, a generally increases as value of attribute, a increases then attribute, b can give a very low relative importance in comparison to attribute, a.

Engineering design can be divided into two categories: conceptual design and detailed design(4). Conceptual design refers to the selection of the most promising design concept. Detailed design refers to the specification of design variable values for a particular design concept. The problem of material selection can also be divided in two parts. First part of the problem requires us, to make decision on, requirement of the component on each attribute and in second part is the numerical optimization to complete the selection. The decision on relative importance of each attribute, stated above, is the conceptual design part of the material selection problem. As such the numerical optimization, which was to be achieved by TOPSIS method, has already been implemented on computer now the conceptual design part of the problem remains to be implemented through computer. It was decided to implement the conceptual part through an expert system. The following sections describe the detailed development of the expert system. Sections describe the each step of development in following manner: Section 2 describes the approach for implementation.

It establishes different relations with the help of designer and provides a numerical values to these relations. Section 3 gives details on using the expert system tool for development of a particular consultation paradigm. In section 4 we present an example and section 5 conclude the method and provides information on other uses of the method.

2. Development of approach for implementation of an expert system

The above approach as such, can not be used for implementation in using an expert system. It needs to be further developed and rules need to be formed so that an expert system shell can be used to implement the approach. A designer can always form general rules for a particular situation, on the basis of some hints, but to implement an expert system, we require a detailed and developed approach, with rules to handle all kinds of situation. First we present a complete approach for assigning relative importance ratios for two attributes in consideration:

i) Establishment of relation in attribute in consideration and its cost.
ii) Establishment of relation in attributes in consideration.
iii) Identifying the relative importance to attributes on the basis of requirements of components.
iv) Formation of rules on the basis of knowledge base.

2.1 Relation in attribute in consideration and cost

As explained earlier, material selection aims at optimizing the objectives, which are cost reduction and functional ratings of the component. We have to strike a balance in two objectives. This need has made us to determine the relation that exists between the values of attribute and cost of materials. To do so we have to study the data stored on the short-listed materials. To do so we have to study the data stored on the short-listed materials obtained after initial short-listing of materials, from the database on materials. To establish a relation in values of attribute for the short-listed materials and cost of the short-listed materials, we have to use the technique outlined in introduction. In the first step, we have to generate a curve between values of attribute a for short-listed materials vs cost of shortlisted materials. Following curves show relations amongst these attributes.

In this technique, this is automatically made from material database and displayed on screen as a step. The designer is suppose to study the curve and answer back to a question asked by computer. We are involving the designer for analyzing the curve and establishing the relation on the basis of it because we
want to avoid the use of computer for analysis which will take a lot of time. Also we want to establish only an approximate relation, which a designer can do with ease. The designer is required to answer the following question:

• If any simple relation can be established for the whole length of the curve? Then give the relation that can be established in the curve of the following simple relation in 2 quantities:

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2.2 Relation in values of attribute a and values of attribute b for shortlisted materials

To optimize at two aims of material selection, that is cost reduction and optimal functional ratings of the component, we also have to study the relation in values of attributes before any value to relative importance of the attributes is assigned. The material selection problem is based upon optimizing the following attributes of material: cost reduction and optimal functional ratings of the component. We also have to study the relation in values of attribute, before any value to relative importance is given to the attribute. As done in the first step here also, we study the curve between, Values of attribute a for short-listed materials and Values of attribute b for short-listed materials. Below we give representation of the four curves.

Figure 4. attribute a vs attribute b

In the expert system this curve is also generated by computers from material database and displayed on the screen. A designer has to study and answer the following questions. Here also we wish to establish only a very approximate relation for the curve, so the designer is involved in the process.

• If any simple relation can be established in two quantities for the whole length of the curve or not. If any relation is there give the relation out of the following that can be establish in two quantities:

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2.3 Third step involves the establishment of relative importance of attribute a with respect to attribute b. This step has been designed so as to obtain uniform response from all the designers. Here designers are required to select only a qualitative statement from the following list, to indicate the importance of attributes a with respect to b for the component design under consideration:

• less important • important • very important • most important

2.4 The last step in our approach is to form rules, on the basis of knowledge base, which are to be utilized to give numerical value to relative importance of attribute a with respect to attribute b for the component in consideration. These rules have been formed for optimizing two basic objectives of the material selection for a component, mainly cost of the product and its functional rating. Following rules were formed:

- The qualitative statements are assigned numerical values as following:

For the relation in the attribute in consideration and its cost:

Rising -» 1.25
Fast rising -» 1.00

Falling -» 1.75
Fast Falling -» 2.00

For the relation in values of attribute b and attribute a:

Rising -» 1.75
Fast rising -» 2.00

Falling -» 1.25
Fast Rising -» 1.00

Rising -» 1.25
None -» 1.50

Falling -» 1.75
None -» 1.50
For the importance of attribute:

- Less important → 1
- Very important → 3
- Important → 2
- Most important → 4

- Multiply the three values to calculate the relative importance value of attribute \(a\) with respect to attribute \(b\).

### 3.0 Implementation of the approach using the Expert System

The above approach is in most suitable form using an expert system. The Rulemaster tool[3] was taken as ideal for writing of small expert system.

The various steps that need to be accomplished using the expert system are:

- Establishing the numerical value of relation in the attribute in consideration and its cost.
- Establishing the numerical value of relation in the attribute \(a\) and attribute \(b\).
- Establishing the numerical value of the importance awarded to attribute \(a\) with respect to attribute \(b\).
- Calculating the numerical value of relative importance of attribute \(a\) with respect to attribute \(b\).

The four tasks are accomplished using the expert system as explained in the following subsections:

#### 3.1 Establishing the numerical value for relation with cost

In our expert system, numerical values given to each expression based on their relation between attribute \(a\) and its cost have been selected arbitrarily. The ultimate function of the TOPSIS method is to provide preferential list of suitable materials. In deciding the list, TOPSIS method requires numerical value of relative importance of attribute \(a\) with attribute \(b\). Now the numerical value does not affect the preferential list, if the basis of deciding the numerical value of all the attribute with respect to other attributes is same. So, even if we took \(a\) as arbitrary numerical value for the relation, it is not going to affect the final list, if the basis remains same for all the attributes. Thus, the value of an expression on relation of attribute \(a\) with its cost is obtained by noting the value stored for the expression. Then the obtained value is stored in the variable called \(a\).

#### 3.2 Establishing the numerical value for relation with attribute \(b\)

Here also the numerical value has been chosen arbitrarily for each expression because we are aware that it is not going to affect the final preferential list of materials. It is to be noted that relation with attribute \(b\) should not affect the value given to relation with cost. This will require that the basis should give numerical value about equal to the numerical value of relation with cost. In fact, in our expert system we have chosen exactly the same values for both the relation with cost and relation with attribute \(b\). Thus the value of an expression on relation of attribute \(a\) with attribute \(b\) is obtained by noting the value stored for the expression. This obtained value is stored in the variable called \(b\).

#### 3.3 Establishing the numerical value for importance with respect to attribute \(b\)

Here again the numerical value has been assigned for each expression. Basis of numerical values very much matches with the basis of numerical values in the first two cases. Also, because this factor has got much more weightage in deciding the relative importance of attribute \(a\) with respect to attribute \(b\). So, numerical values are generally double the numerical values in first two cases. Numerical values are read from the database and stored in the variable called \(c\).

#### 3.4 Calculating the numerical value of relative importance of attribute \(a\) with respect to attribute \(b\)

The established numerical values of relation with cost, relation with attribute \(b\), relation of importance are used to calculate the numerical value of relative importance. In fact to keep it simple we multiply the three values and obtain the resultant value as the numerical value of relative importance of attribute \(a\) with respect to attribute \(b\).

### 4.0 Illustrative example for Material Selection problem

The above approach for calculating the numerical value of relative importance of attribute \(a\) with respect to attribute \(b\) is explained in this section with reference to a typical example. The four steps that are accomplished in calculating the numerical value are explained in what follows:

- The relation found in the attribute \(a\) and its cost was Rising. The system asked the question relation found with cost. We answered for this query by typing in Rising. Then the system assigned and store a numerical value to it. After that, it again asked relation found with attribute \(b\). We answered
the query by typing in **Falling**. Then the system assigned and store numerical values to it. Lastly the system asked **Importance of attribute for component** ?. We answered by typing in **Important** then the system provided us the numerical value of relative importance of attribute.

5.0 Conclusions

In all types of design problems, the designer has to make both conceptual decision and detailed design decisions. The first type of decision is very suitable for solving by reasoning and in second type of decision-a designer has to converge upon a solution by iteratively evaluating a mathematical model of the problem. Optimization algorithm provide an efficient, powerful means to simultaneously adjust all variables to improve an objective and satisfy constraints. Expert system provide an efficient way of applying reasoning and arriving at the solution to our problem by establishing relations between attributes and cost.

In our system, the main objective was to optimize on the cost of the component and its functional rating. But the design of the system, in a specialized case is such that we have to optimize on cost, or any other attribute like quality, then we have to only replace the cost with quality in the system. This will achieve optimization of other attribute as well with optimization of quality in place of cost. This makes our system versatile for use in industry, which in general wants to optimize some special property in place of cost for some components for machine.

**References**


3. **Rulemaste 2.0**, Radian Corporation Inc., U.S.A.


