A Computerized Procedure for Determining the Suitable Number of Positive Decisions in the Weighted-Properties Method

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Abstract

Nowadays, the selection of materials in automatic way is a very important consideration. In this research, an system is built in a logic sequence, acceptable and easy for use by the user with a possibility of using it on unlimited number of applications. The use of this system leads to calculate the number of positive decisions (m) which is a very important factor in the weighted properties method that is used in the selection of engineering materials. This system considers multiple choices in the difference of the important sequence or equality of importance for some properties. Results proved the efficiency of this system in calculating the value of m, so this system can be considered parallel to the other methods that have been used to determine m value except that the suggested system can determine m in a computerized way and represents an important direction in the building of automated system for engineering materials selection.

Keywords: weighted properties, computerized selection of material.

أعداد أسلوب برمجي لايجاد عدد القرارات الايجابية الملائمة باستخدام الطريقة الوزنية

الخلاصة

أن اختيار المواد بصورة تلقائية يمثل اعتباراً مهماً جداً في هذه الأيام. في هذا البحث ، تم بناء نظام ذو تتابع منطقي مقبول وسهل التطبيق من المستخدم مع إمكانية استخدامه على عدد غير محدد من التطبيقات. ان استخدام هذا النظام يؤدي الى حساب عدد القرارات الإيجابية (m) الذي يمثل عاملاً مهماً جداً في الطريقة الوزنية المستخدمة لاختيار المواد الهندسية. هذا النظام يأخذ بنظر الاعتبار حالات متعددة من حيث اختلاف تسلسل الأهمية أو تساوي الأهمية لبعض الخواص.

أثبتت النتائج كفاءة النظام في حساب قيمة (m)، وبذلك فان هذا النظام يمكن اعتباره موازيا للطرائق المستخدمة في حساب قيمة (m) الا إن النظام المعد يقوم بتحديد (m) بصورة مبرمجة ويمثل اتجاهاً مهماً في بناء نظام مؤتمت لاختيار المواد الهندسية.

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Introduction:

It is said that there are more than 50000 materials available to the engineer. Materials enter all aspects of engineering design, from the most integrated of microelectronics to the most massive of civil engineering structures. The range of materials available to the engineer is larger and is growing faster. New materials create opportunities for innovation, for new products and for the evolutionary advance of existing products to give greater performance at lower cost [1].

The word "selection" is central to engineering field. The choice may be of a material (a metal, a ceramic, polymer, a composite...); a manufacturing process (casting, forging, injection, molding...); a shape (I-section, tube...); ...[2].

Materials selection enters at every stage of the design process, but the nature of the data for the material properties required at each stage differs greatly in its level of precision and breadth. The design stage, the designer require approximate data for the widest possible range of materials. All options are open, a polymer may be the best choice for one concept, and a metal for another, even through the function is the same [3].

There is an extensive literature on materials selection but all textbooks treat the subject in terms of information, which must be learned rather than techniques to be acquired. Typically the subject is presented as lists of materials with typical properties and extensive examples of their use [4]. The difficulty in selecting materials is occasioned because no one individual can possibly possess in depth knowledge of all types [5], so the question is how to find one's way through the enormous catalogue of materials, narrowing it down to a single sensible choice, and to device a rational procedure for material selection [1], and if so, the systematization of procedures is essential [3].

The problem can arise of trying to determine the optimum material where there are a number of required properties or property indices and a number of materials meeting the different properties in different ways. The issue is then to determine the material, which achieves the best balance of properties [6].

There are many different ideas on how material selection for a product should be made [7]. One way of doing this is the use of merit rating or weighted properties method [8,9]. The main factor in this method is the number of positive decisions (m) which is the basis of our work by building a computerized approach.

Weighted-property method:

The performance of an engineering component is limited by the properties of the material of which it is made. Under some circumstances a material can be selected satisfactorily by specifying ranges for individual properties and the performance depends on a combination of properties [10].

The weighted property method can be used in evaluation of complicated combinations of materials and properties [8]. In this method each material property is assigned a certain weight (weighting factor α), depending on its importance, and each material is assigned a Merit (M) for each property [6,8,9,11]. A weighted property value or Weighting Merit (WM) is obtained by multiplying the Merit (M) by the weighting factor (α). The individual weighted property values of each material are then summed (ΣWM) to give a comparative materials performance index (γ). The material with the highest γ is considered to be the best.

In its simple form the weighted property method has the drawback of having to combine unlike units, which could yield irrational results. This is particularly true when different mechanical, physical and chemical properties with widely different numerical values are combined. The property with higher numerical value will have more influence than is warranted by its weighting factor. This drawback is overcome by introducing scaling factors. Each property is so scaled that its highest numerical value does not exceed 100. When evaluating a list of candidate materials, one property is considered at a time. The best value in the list is rated as 100 and the others are scaled proportionally. Introducing a scaling factor facilitates the conversion of normal material property values to scaled dimensionless values. For a given property, the scaled value (M) for a given candidate material is equal to [9]:

M=(numerical value of property) ×100/(maximum value in the list).. (1)

where *M* is the merit.

By this procedure, each property is given equal importance and affects the comparative materials performance index (γ) according to its weighting factor only [9,11].

For material properties that can be represented by numerical values application of the above procedure is a simple matter; but with properties like corrosion and wear resistance, service life, weldability, and so forth, numerical values are rarely given. In such cases the scaling of the material properties will have to be derived from test data and previous experience. It should be noted that in some applications, certain material properties are more desirable when they have lower numerical values as in the case of cost, density, electrical resistivity, weight gain in oxidation and so forth. For these properties the lowest value, rather than the highest, should be rated as 100, and its merit can be calculated as follows [9]:

M=(minimum value in the list)× 100 /(numerical value of property)……(2)

Determination of the Total Number of Positive Decisions (m):

(m) is considered one of the most important factors that affect the application of weighted properties method for engineering material selection. Because with (m), (α) can be calculated, then WM and finally (γ) for the optimum solution.

Determination of (m) depends on the importance of each property, and from some references as [6] the determination of (m) has been done by giving a non-specified number, the minimum value of property is given a lowest number then the number increases to reach the most important property regardless of the summation of those numbers. So, this method is not accurate in giving the final results while [9] uses the digital logic method in the calculation of (m) and it is inaccurate since it does not give the same value of (α) that he used in his case study as he mentions. Therefore, a logic system was built to calculate (m) in an acceptable way.

Determination of weighting factor (α):

The determination of weighting factor (α) depends on the determination of the total number of possible decisions (N) and the total number of positive decisions (m) [9,11].

The total number of possible decisions (N) can be calculated as follows [9].

$$N = n\,(n - 1)\,/\,2 \;\ldots\ldots\; (3)$$

where n: the number of requirements (properties) under consideration.

If the total number of positive decisions (m) is calculated for each property (which is the aim of this research) then the summation of the total number of positive decisions for all requirements (Σm) should be equal to the total number of possible decisions (N)(i.e $\Sigma m = N$) [9]. The weighting factor (relative emphasis coefficient) (α) for each property can be calculated as[9]:

$$\alpha = m\,/\,N \;\ldots\ldots\ldots\; (4)$$

And $\Sigma\alpha = 1$

Suggested System for Determining m Value:

In this system, a logic approach was built and its final result is the value of the positive decisions number (m) for each property of the engineering properties, where the value of (m) varies according to the importance of each property within a specific application. So, this system was built to consider the basic rules in the arrangement of (m) values on the application properties, and from these rules:

1. Unequal decrease in the difference of (m) value upon changing from one property to another, from the most important property to the lowest important property.
2. Consider that some properties are equal in importance where (m) value will be equal in those properties.
3. The summation of weighting factors (α) must be equal to 1

$\Sigma\alpha = 1$

4. The summation of Positive Decisions number values of all properties must be equal to the number of the possible decisions (N).

$\Sigma m = N$

According to the above information, a sequence of logical system was built and can be summrized in figure (1).

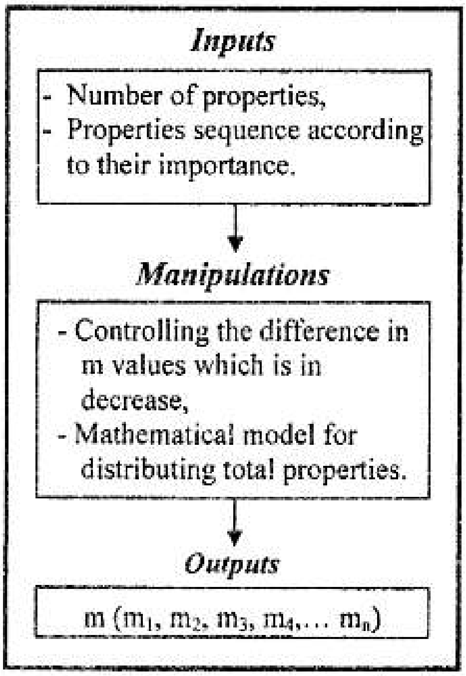

Figure (1) Sequence of work

Figure (1) can be explained in detail as followed:

1. First Step (inputs):

In this step, the selection engineer inputs the number of properties and its sequence in importance from the property which is most important to the lowest important property.

2. Second Step (Manipulations):

This step has two stages:

2.1. First Stage (Controlling the difference in m values which is in decrease):

When specifying a certain number of properties and their importance to the program you will determine certain value of (m) to the first property and then determine another value to the second property and so on. To reach the last property in such number of times in which there is decrease in the difference between two values of (m) starting from the most important value. This will follow this relationship:

Σ number of difference between two values for all values of m=n - 1 ...... (5)

$$\begin{array}{ll} & m_1 \;\rceil\; m_1 - m_2 \\ m_2 - m_3 \;\lceil & m_2 \;\rfloor \\ \;\;\;\;\;\;\;\;\;\;\;\;\;\lfloor & m_3 \\ & m_4 \\ & \vdots \\ & m_n \end{array}$$

(where n = number of properties)

Relation (5) is correct when:

1) $m_1 \neq m_2 \neq m_3 \neq \ldots\ldots \neq m_n$

2) $m_1 - m_2 \neq m_2 - m_3 \neq \ldots\ldots \neq m_{n-1} - m_n$

3) $m_1 - m_2 > m_2 - m_3 > \ldots > m_{n-1} - m_n$

For an example, when the number of properties is (9), then the number of divisions (the difference between each two values of m) will be (8), as in table (1), in that case the difference between each two values is not equal to the difference between the next two values of m.

But if there are some properties which have equal importance, then the program will specify (m) value by giving them equal values, and the program will not decrease the difference when moving from property to another (both have the same importance) but will make the difference equal to zero. If we take the same previous example where the number of properties is (9) and suppose that the properties 2 and 3 (yield strength and ultimate strength) are equal in importance, also the properties 5, 6 and 7 (hardness, corrosion and thermal) are equal in importance, then the number of divisions will be according to this relationship:

Σ number of difference in m value (divisions) = n – (number of value that equal to zero + 1) ...... (6)

So, the number of values, that are equal to zero when the properties 2 and 3 are equal in importance, is one value only, and when the properties 5, 6 and 7 are equal in importance there will be 2 values equal to zero as shown in table (2).

Table (1) Example of determining D for unequal properties in importance.

Seq.	Property	m
n_1	Fatigue strength	m_1
n_2	Yield strength	m_2
n_3	Ultimate strength	m_3
n_4	Young's modulus	m_4
n_5	Hardness	m_5
n_6	Corrosion resistance	m_6
n_7	Thermal conductivity	m_7
n_8	Wear resistance	m_8
n_9	Cost	m_9

No. of divisions = 8

> $m_1 - m_2 = D_1$
> $m_2 - m_3 = D_2$
> $m_3 - m_4 = D_3$
> $m_4 - m_5 = D_4$
> $m_5 - m_6 = D_5$
> $m_6 - m_7 = D_6$
> $m_7 - m_8 = D_7$
> $m_8 - m_9 = D_8$

Table (2) Example of determining D for equal properties in importance.

Seq.	Property	m
n_1	Fatigue strength	m_1
n_2	Yield strength	m_2
n_3	Ultimate strength	m_3
n_4	Young's modulus	m_4
n_5	Hardness	m_5
n_6	Corrosion resistance	m_6
n_7	Thermal conductivity	m_7
n_8	Wear resistance	m_8
n_9	Cost	m_9

No. of divisions = 5

> $m_1 - m_2 = D_1$
> $m_2 - m_3 = 0$ → Group No.1
> $m_3 - m_4 = D_2$
> $m_4 - m_5 = D_3$
> $m_5 - m_6 = 0$ } Group No.2
> $m_6 - m_7 = 0$ }
> $m_7 - m_8 = D_4$
> $m_8 - m_9 = D_5$

2.2. Second Stage (Mathematical model for distributing total properties):

In this stage, a certain way was suggested to help in determining m value and this way can be explained as follows:

Dividing the number of possible decisions into 2 equal values, each value represents (0.5 N). One of the values (value1) will be divided equally by the number of properties to obtain a constant value (c_1).

$C_I = 0.5\,N / n$ ...... (7)

Then each property will be given different number of units which represents the property weight according to its importance with unequal decreases (from most importance to the lowest).

The way used to determine property weight depends on the decreases in difference (or number of divisions D) as example if D=8 (for unequal properties in importance as in table 1), then:

$U_1 = 8+7+6+5+4+3+2+1 = 36$ Units,
$U_2 = 7+6+5+4+3+2+1 = 28$ Units,
$U_3 = 6+5+4+3+2+1 = 21$ Units,
$U_4 = 5+4+3+2+1 = 15$ Units,
$U_5 = 4+3+2+1 = 10$ Units,
$U_6 = 3+2+1 = 6$ Units,
$U_7 = 2+1 = 3$ Units,
$U_8 = 1$ Unit,
$U_9 = 0$.

For equal properties in importance as in table(2) (where D=5) then:
U_1 = 5+4+3+2+1 = 15 Units,
U_2=U_3=4+3+2+1 = 10 Units,
U_4 = 3+2+1 = 6 Units,
U_5=U_6 = U_7 = 2+1 = 3 Units,
U_8 = 1 Unit,
U_9 = 0 .

Note that U2 took the rational sequence and U3 took the same value of U2, because they have equal importance , and U5,U6 and U7 will be submitted to the same procedure. Figure (2) illustrates the relationship between the properties (n=9) and its weight (for unequal properties), and figure (3) illustrates the relationship between the properties and their weight (for some equal properties).

3. Third Step (outputs: Determination of m value):

After determining the number of units (property weight) in the previous step, the total number of units (ΣU) for all properties will be determined $U_T = \Sigma U$, then the other value in the previous step (value2=0.5N) will be divided by U_T to calculate a constant (C_2).

$C_2 = 0.5\,N / U_T$ ...... (8)

The final step is determining (m) value by the equation:

$m = C_1 + (C_2 \times U)$ ... (9)

From this equation, (m) value depends on the property weight.The algorithm of the program is represented in figure (4).

Program profile:

Figure (5) illustrats the main form of the program. The form is divided into several parts, where there is a part related to specify the number of properties (n) which is considered an input. Another part is divided to several groups for the purpose of specifying the equal properties in importance. For example the number of properties (n) is (9) as in the example in step 2, if the properties 2 and 3 are equal in importance, then group No.1 will be activated, after that number 2 will be specified in text 1 and number 3 will be specified in text 2 to make sure that the properties which are equal in importance are property 2 and property 3.

If there is another property which is equal in importance, then another group will be activated. In the same example, the properties (5, 6 and 7) are equal in importance too, so number 5 will be specified in text1 of group No.2 and the number 7 in text 2 of group 2. If there is another equal property, then another groups will be activated in the same procedure. The other part of program represents a list of outputs, which are m values arranged from the most important property to the less important one. Also there is another part which calculates the number of possible decisions (N).

Case study:

In this case an example consisting of 5 properties with two equal properties (4 and 5) which be taken and the program will be applied to them. The result will show m values, as in the following procedures:

1.Calculate the number of possible decisions.

N = 5 (5 - 1) / 2 = 10

2.Calculate the number of difference (divisions) in m values which is in decrease according to relation number (6) because of the presence of equal properties in importance. Since the number of equal properties in importance is 2, then the number of values that are equal to zero is one value only. So the number of division is:

Number of divisions = 5-(1 + 1) = 3

3.Divide N into two equal values, where:

Each value = 0.5 N = 5

Value1 will be divided by the number of properties (n) to obtain a constant value (C_1).

$C_1 = 0.5\ N / n = 0.5\ (10) / 5 = 1$

where each property will take a constant value equal to 1.

4.Calculate the property weight according to its importance (where D=3) as follows:

$U_1 = 3 + 2 + 1 = 6$ units

$U_2 = 2 + 1 = 3$ units

$U_3 = 1 = 1$ unit

$U_4 = 0$ unit

$U_5 = 0$ unit

5.Calculate the total summation of properties weights in units as following:

$U_T = \Sigma\ U = 6 + 3 + 1 = 10$ units

6.Calculating the constant C_2

$C_2 = 0.5\ N / U_T = 5 / 10 = 0.5$

7.Calculate m values as follows:

$m_1 = C_1 + (C_2 \times U_1) = 1 + (0.5 \times 6) = 4$

$m_2 = C_1 + (C_2 \times U_2) = 1 + (0.5 \times 3) = 2.5$

$m_3 = C_1 + (C_2 \times U_3) = 1 + (0.5 \times 1) = 1.5$

$m_4 = C_1 + (C_2 \times U_4) = 1 + (0.5 \times 0) = 1$

$m_5 = C_1 + (C_2 \times U_5) = 1 + (0.5 \times 0) = 1$

Fiqure(6) illustrates the results.

After that the weighting factor (α) can be calculated and proceed to the next sequence in the weighted properties method of materials selection.

Conclusion:

The suggested system had proved a high efficiency in the determination of the number of positive decisions (m). The method used to find m in this research is parallel to other methods that used to find this value which did not mention in details how to find m value, and there is no single way that explains clearly how to find m, so this method is effective in finding m.

The user can apply this system to unlimited number of properties and applications, in a very simple and easy way.

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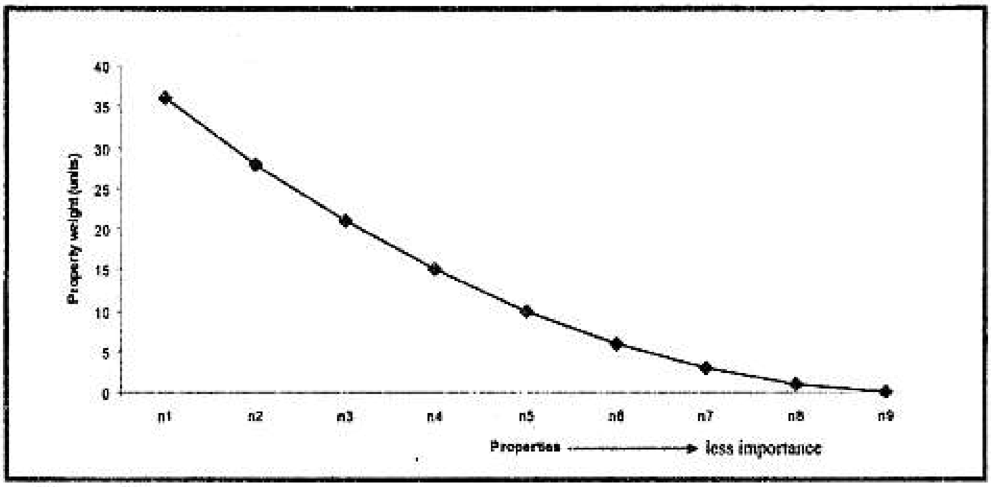

Figure (2) Relationship between the properties and their weights (for unequal properties)

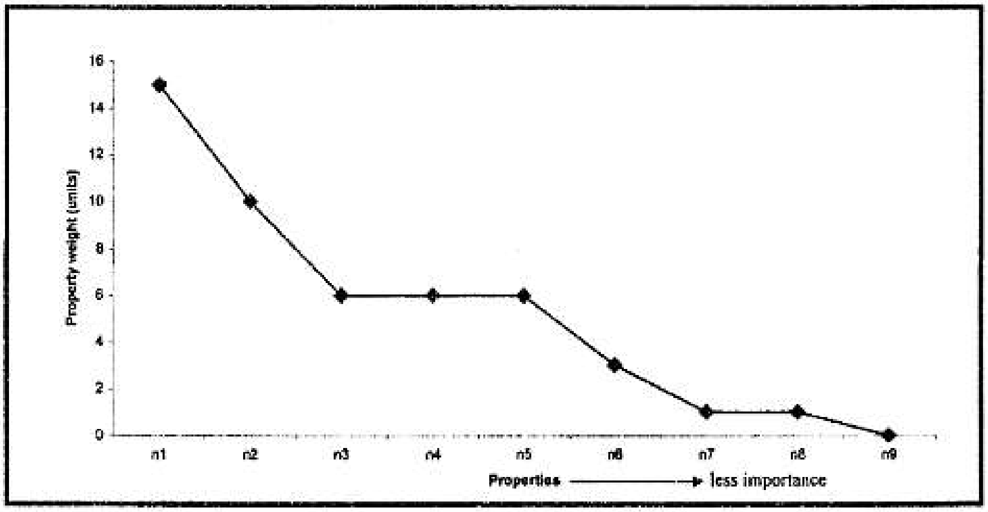

Figure (3) Relationship between the properties and their weights (for some equal properties)

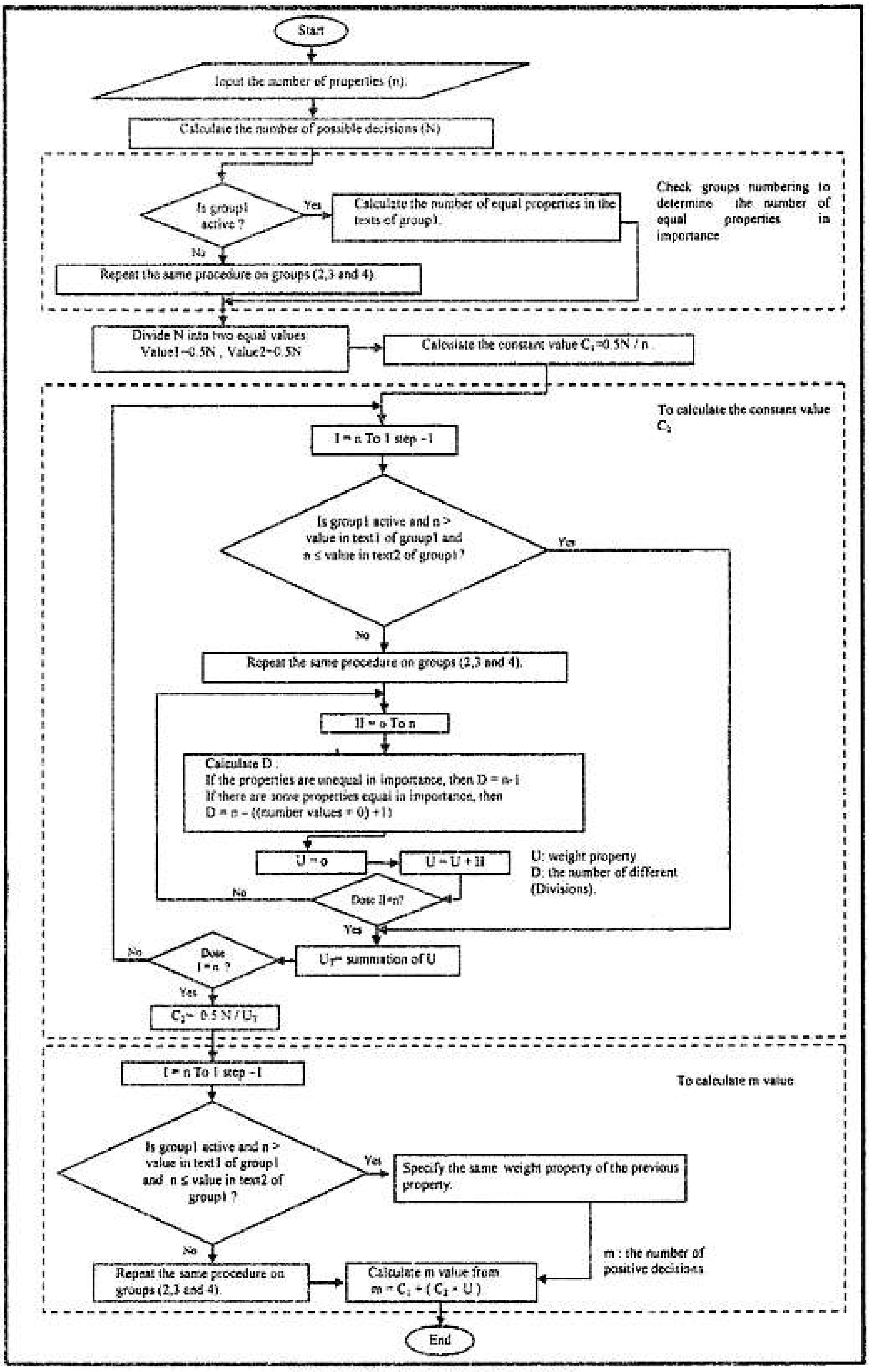

Figure (4) Program algorithm.

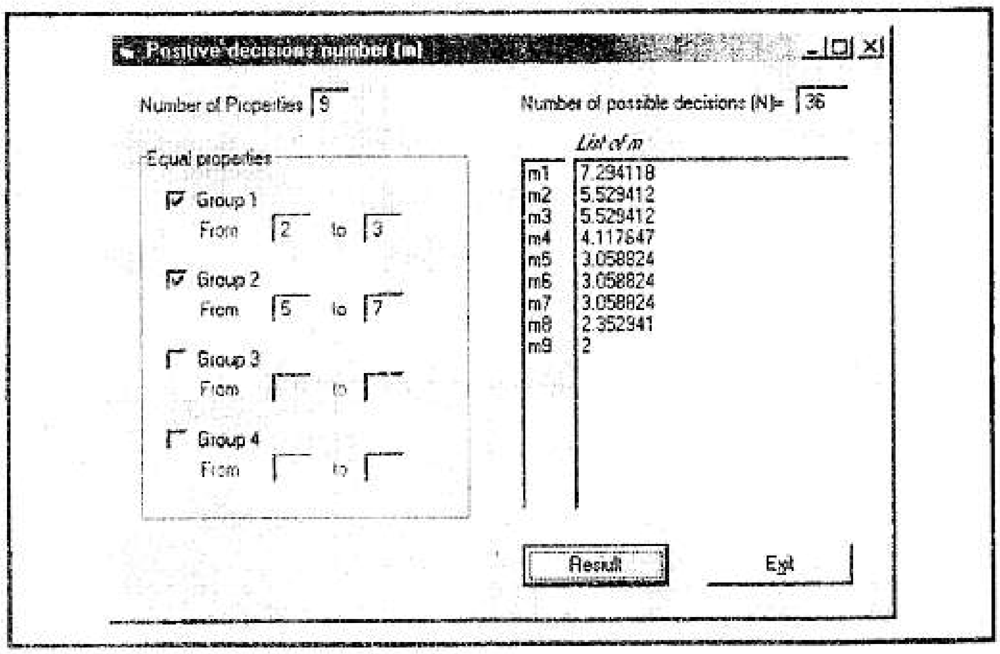

Figure (5) Program profile.

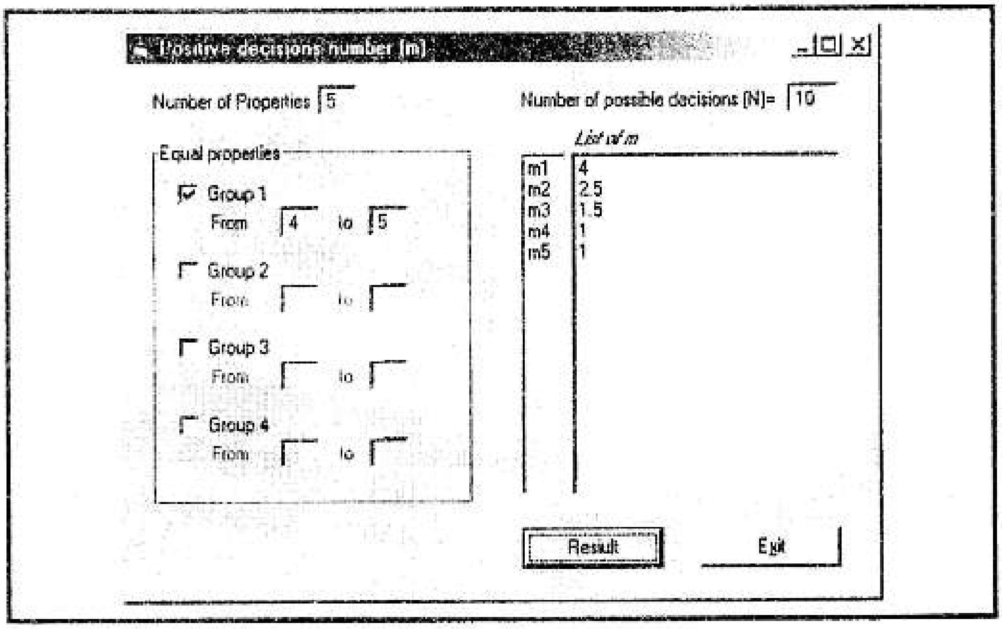

Figure (6) Program profile.