MULTIPLE CRITERIA DECISION MAKING: AN APPLICATION EXAMPLE IN ORTHODONTICS

Horațiu Colosi
"Iuliu Hațieganu" University of Medicine and Pharmacy,
str. Emil Isac, nr.13, Cluj-Napoca, Romania; e-mail: hcolosi@umfcluj.ro

Ștefan Țigan
"Iuliu Hațieganu" University of Medicine and Pharmacy,
str. Emil Isac, nr.13, Cluj-Napoca, Romania; e-mail: stigan@umfcluj.ro

ABSTRACT

The paper presents some basic principles of multiple criteria decision making, followed by an example of its implementation in a matter of choosing between several orthodontic protrusion springs.

KEYWORDS: decision making, orthodontic spring

1. INTRODUCTION

Multiple criteria decision making consists in choosing the optimum alternative from a finite set of alternatives that can be compared with each other, based on a finite number of criteria. These criteria can be represented on either an ordinal or a numeric scale, in both situations the desired goal being either a maximization or a minimization of individual criteria. Each alternative must be characterized in respect of every criterion.

The goal of such a decision making model is helping the deciding factor to choose, either the best alternative, or a set of apparently "good" alternatives, or to arrange the studied alternatives in descendent order of their desirability.

For instance, in medical sciences, a decision making model can be used in order to choose the best solution between several therapeutical options.

In our paper we present an example of multiple criteria decision making, applied in the particular field of orthodontics. In this particular example, the problem consisted in choosing between several technical possibilities of producing the same type of tooth movement.

2. BASIC PRINCIPLES OF MULTIPLE CRITERIA DECISION MAKING

Ideally, when faced with choosing between several possible alternatives, the deciding factor needs to find the optimum combination of characteristics or criteria in order to choose one or the other proposed solution as the best, or optimum one.

The principle of optimization is not always easy to implement, due to the necessity of complete information about all possible alternative combinations, about relative differences between alternatives and all the restrictions that could influence the decision making process. [1], [2], [3], [4]

Given the limitating nature of these restrictions in finding a solution to most real life problems, Van Delft and Nijkamp [4], cited by [3], proposed a “compromise” principle, stating that any valid solution needs to reflect a compromise between different priorities. Meanwhile, differences between actual results and ideal ones can be converted using pondering factors, expressing the preference for one or the other of the variants.

The preliminary analysis that needs to be performed for any multiple criteria decision making consists of three successive steps:

1. Defining the set of possible alternatives
2. Describing the consequences of the alternatives (such as their performance, efficiency, financial aspects, etc.)
3. Defining the criteria and their evaluation means

In order to describe a model for multiple criteria decision making, the set of possible alternatives can be symbolized as $A=\{a_1, a_2, \dots, a_m\}$ and the set of criteria as $K=\{k_1, k_2, \dots, k_n\}$. Each alternative a_i, $_{i=1,2,\dots,m}$ can be associated to a vector representing the evaluation result of the specific alternative regarding the criteria $k_{j,\ j=1,2,\dots,n}$. These vectors form the lines of a matrix, C, called the *evaluation matrix*:

Criterion / Alternative	k_1	k_2	…	k_n
a_1	c_{11}	c_{12}	…	c_{1n}
a_2	c_{21}	c_{22}	…	c_{2n}
…	…	…	…	…
a_m	c_{m1}	c_{m2}	…	c_{mn}

Table 1. Evaluation matrix

If all criteria in the evaluation matrix are numeric (cardinal), the decision problem is called a cardinal multiple criteria decision problem.

If all criteria in the evaluation matrix are ordinal, the decision problem is called an ordinal multiple criteria decision problem.

A criterion for which the better values are the higher ones is called a maximum criterion, while a criterion for which the better values are the smaller ones is called a minimum criterion.

Sometimes, not all evaluated criteria have the same level of importance. The deciding factor may then attribute importance coefficients, $w_{j,\ j=1,2,\ \ldots,n}$, to every criterion, thus forming an importance vector $W=(w_1, w_2, \ldots, w_n)$, associated with the evaluation matrix.

In order to determine the solutions of multiple criteria decision making problems, several methods have been developed, depending on the evaluation matrix containing heterogeneous, numeric or non-numeric data. If the data contained in the evaluation matrix is heterogeneous, it first needs to become homogenous. This can be done using a procedure called normalization of data.

Direct methods arrange the alternatives based on functions that measure the utility of each alternative with regard to all criteria. These functions are called utility functions. One of the more usual functions is the additive utility function:

$$U(a_i) = w_1 c_{i1} + \ldots + w_n c_{in} ,$$

in which $W=(w_1, w_2, \ldots, w_n)$ is the importance vector associated with the evaluation matrix. [3]

3. APPLICATION EXAMPLE OF MULTIPLE CRITERIA DECISION MAKING IN ORTHODONTICS

When planning orthodontic treatment, the same type of tooth movement can be obtained using several technical possibilities regarding the design of the springs that will apply orthodontic forces on malpositioned teeth.

For instance, a protrusion movement of teeth can be performed using several alternative spring designs. Some of the usual spring designs imagined for tooth protrusion are:

- the open protrusive spring
- the closed protrusive spring
- the vestibulisation spring for molars and premolars
- the unique console spring

- the double console spring
- the "T" spring

In choosing between these alternatives, the orthodontist can use different criteria and every criterion can be given a different importance coefficient, depending on the case to be treated.

In our example, the six orthodontic springs mentioned above have been evaluated with regard to eight criteria, as seen in table 2.

Apart from the first criterion (wire thickness), which can be measured directly on orthodontic wires, all other criteria have been ranked on a 1 to 10 scale, 1 representing the least desirable and 10 the most desirable value to be obtained by an evaluated spring regarding a particular criterion.

Criterion / **Spring type**	**Wire thickness (fracture resistance) [mm]**	**Spring flexibility**	**Possibility to combine a proximal tooth movement**	**Possibility to combine tooth derotation**	**Possibility to be adapted in narrow space**	**Easy to construct**	**Easy to activate**	**Easy to wear**
Open protrusive spring	0,6	8	10	9	9	9	9	9
Closed protrusive spring	0,6	6	2	8	8	8	8	8
Vestibulisation spring for molars and premolars	0,8	5	4	1	10	7	10	8
Unique console spring	0,5	9	10	9	6	6	8	6
Double console spring	0,5	7	6	8	8	5	9	7
"T" spring	0,5	6	2	7	5	5	7	8
Importance coefficient	**3**	**3**	**1**	**1**	**1**	**2**	**2**	**2**

Table 2. Evaluation matrix of orthodontic protrusion springs

The normalized evaluation matrix, $R=[r_{i,j}]$ in table 3 has been obtained using the following transformation: $r_{ij} = \frac{c_{ij}}{c_j^{\max}}$.

Criterion / Spring type	Wire thickness (fracture resistance)	Spring flexibility	Possibility to combine a proximal tooth movement	Possibility to combine tooth derotation	Possibility to be adapted in narrow space	Easy to construct	Easy to activate	Easy to wear
Open protrusive spring	0,75	0,888	1	1	0,9	1	0,9	1
Closed protrusive spring	0,75	0,666	0,2	0,888	0,8	0,888	0,8	0,888
Vestibulisation spring for molars and premolars	1	0,555	0,4	0,111	1	0,777	1	0,888
Unique console spring	0,625	1	1	1	0,6	0,666	0,8	0,666
Double console spring	0,625	0,777	0,6	0,888	0,8	0,555	0,9	0,777
"T" spring	0,625	0,666	0,2	0,777	0,5	0,555	0,7	0,888
Importance coefficient	**3**	**3**	**1**	**1**	**1**	**2**	**2**	**2**

Table 3. Normalized matrix for evaluation of orthodontic protrusion springs

Subsequently, the global score method has been used in order to determine the ranking score for every alternative orthodontic spring:

$$s_i = \sum_{i=1}^{number\_of\_criteria} r_{ij} \cdot w_j \ .$$

4. RESULTS

After applying this algorithm, the highest score (13,614) has been reached by the open protrusive spring, therefore representing the optimum solution for the given combination of characteristics and importance coefficients.

The descending order for the global scores of all 6 evaluated springs has been:

1. Open protrusive spring : 13,614
2. Unique console spring : 11,739
3. Vestibulisation spring for molars and premolars : 11,506
4. Closed protrusive spring : 11,288
5. Double console spring : 10,958
6. “T” spring : 9,636

5. CONCLUSIONS

As seen from the example above, decisions regarding treatment alternatives can be facilitated by means of multiple criteria decision making, but one should always keep in mind that the results of any decision making method are very much dependent on the set of criteria taken into consideration, on subjective evaluation scores attributed to every alternative in the evaluation matrix, as well as on the importance coefficients associated to every criterion by the evaluator.

Therefore, different evaluators may start with different premises regarding subjective criteria, such as the easiness to build or activate a certain spring. Evaluators may also add or remove criteria for their evaluation, as well as associate different importance coefficients to every criterion, depending on the specific case to be treated.

All these aspects may influence the final ranking of each treatment alternative represented in our example by six orthodontic protrusion springs.

Multiple criteria decision making methods offer several different variants for ranking existing alternatives. Ranks obtained with different methods can be aggregated using the assignment model procedure [1], [3].

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