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USING THE MULTI-CRITERIA ANALYSIS FOR THE QUALITATIVE AND QUANTITATIVE APPRAISAL OF THE SOLUTIONS OF INDUSTRIAL DESIGNERS

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Organizing the varied results offered by different designers for the same problem, product etc. by value is presently quite a difficult task. This aspect, from a comprehensive approach, is equivalent with the making of a classification, at the same time qualitative and quantitative, worked through the perspective of some criteria set by the beneficiary.

Arranging the diverse solutions offered by different designers for the same problem, product etc. by value is presently quite a difficult task. This aspect, from a comprehensive approach, is equivalent with the making of a classification, at the same time qualitative and quantitative, worked through the perspective of some criteria set by the beneficiary.

Presently, the draw backs detected at such projects were:

- Almost no method regards al criteria that should be considered. Only the most important criteria are considered, with the minor ones discarded. This is criticisable, because sometimes the analysis through the point of view of several minor criteria can overturn the result achieved through the point of view of a major criterion.
- Usually, the classification aim at just the qualitative aspect that is the classification in inverse order of the regarded solutions.
- The value (score) of the solutions, ordered by the qualitative classification, is difficult to establish with most of the present methods; actually, just this aspect of value (score) represents the quantitative aspect of the qualitative classification.

The paper presents the multi-criteria analysis, improved by some proposals by the author, as well as its application drawing up a classification for the results of three different teams of designers, which developed the dashboards of three medium class, mass production automobiles.

1. THEORETICAL BASIS

The multi-criteria analysis [BCL1998], [BOC1997] can be applied successfully in various areas and situations:

- for different types of classifications;
- in the design of a creation (technical or of a different nature);
- for the comparative appraisal of several creation variants (or objects or subjects) and if it is required, the selection of the most appropriate variant, based on the appraisal;
- at the sorting by value, based on given criteria, of several variants for the same achievement;
- for the comparison of one or several personal realisations with existing variants of a product, object, method etc.

It is interesting to observe that this type of analysis can be used to obtain all types of

classifications with subjects from the same scope or from different scopes, contemporary or not, where the subjectivity s removed to a great extent.

For example, it can be established who is the best cyclist, or actor etc. of all times. Or a unique classification can be put together of the most prolific creators world wide or from a specific country, regardless of the domain they worked in.

Also, it can be scientifically established which variant of approach is better for an individual, when he has several variants at his disposal. The example can go on and on.

It is important that the multi-criteria analysis presents, in respect to the chosen criteria, an analysis which has a largely objective character to its results. This is for the following reasons:

- the order of the criteria is established by comparing two criteria to each other;
- it regards, through a simple mathematical expression, that the relative position of two criteria can only have three situations: *a criterion is more important than the other, a criterion is equally important as the other* and *a criterion is less important than the other*;
- when analysing by comparison the different variants, the analysis is performed separately through each criterion.

The analysis goes though 5 stages.

1.1. ESTABLISHING THE CRITERIA

A *criterion* is a clearly defined point of view of the specialist in the scope, through which he (alone or with a team) limits, individualises, defines certain proprieties, attributes, characteristics that assess the object being analysed.

The important criteria has to be established (which of course are several – that is why this type of analysis is often called multi-criteria) which will lead to a pertinent characterisation, lacking ambiguity.

One or two BRAINSTORMING session are recommended for the finding and establishing of the criteria for multi-criteria analysis, followed by a morphological analysis.

1.2. DETERMINATION OF THE WIEGHT FACTOR FOR EACH CRITERION

This determination is finalised by calculating the so called *weight factors*.

The weight factor is assessed on three value *Latin grid*.

A quadratic table is composed, which has on the rows and also on the columns the respective criteria on number *N*. In this table each criterion is compared against the others, with the entry on the each row and exit on each the column. When the criterion is on a row compared with the criterion on a column if it is:

- more important, the value 1 is assigned;
- equally important, the value ½ = 0,5 is assigned;
- less important the value 0 is assigned.

On the main diagonal of the quadratic table of criteria, only values of ½ are entered, because a criterion can not be more or less important than itself.

The sum of all point in such a table is always equal to half of the square of criteria number.

On each row the sum of all criteria is calculated, thus establishing the level (placement) compared to the others. The value of the level concurs with the place in the classification of

the criteria. If two (or more) criteria score the same number of points, the level will have as value the semi-sum (or fi there are more, the arithmetic mean) of places (successive) of the respective criteria in the classification of the criteria; thus the level can also be a decimal ratio. The criterion which got the most number of points will be placed on the first level (the first position). The criterion which got the least number of points will be placed on the last level (the last position).

The weight factors (γ_i) can be calculated with different formulae.

For the practical application the FRISCO formula (empiric formula given by a renowned creation group from San Francisco - USA) was chosen, a formula which has been recognised world wide as being the most performant and mostly used:

$$\gamma_i = \frac{p + \Delta p + m + 0{,}5}{-\Delta p' + \frac{N}{2}} \tag{1}$$

where:

- p is the sum of the points (on a row) scored by the analysed element;
- Δp – the difference between the score of the analysed element and the score of the element on the last level; if the regarded element is the element on the last level, Δp will have the value 0;
- m – number of criteria outranked (standpoint of the score) by the regarded criterion;
- N – number of regarded criteria;
- $\Delta p'$ – difference between the score of the regarded criteria and the score of the first criteria (resulting in a negative value); if the regarded criteria is the one place on the first level, the result will be 0.

1.3. IDENTIFICATION OF ALL VARIANTS

The variants refer to subjects, products, objects, realistic solution that answer the same purpose, use, calculations etc.

1.4. GRADING *N*

The grade has to be an integer (maximal grade 10). It is also called importance grade or grade of contribution to a criterion.

The mark is awarded to each variant, according to each criterion. That means each variant is analysed in turn, through each criterion, until all variants are assessed.

1.5. CALCULATION OF THE PRODUCT BETWEEN THE *N* GRADES AND THE WEIGHT COEFFICIENTS

This calculus is performed in a table called consequence matrix.

At last the sum of these product is being calculates; the sums (usually unique values, associated to each variant) will determine a final classification. The variant with the highest

score will be placed on the first position. If the scores of the variants are close , that means the respective variants have similar performances.

2. EXAMPLES

A completed multi-criteria analysis, as well as two modalities for choosing the criteria and calculating the weight factors were chosen for exemplification. This type of analysis is used increasingly due to the remarkable results obtained in the most diverse areas that require a creative research.

2.1. ERGONOMY OF THE COMMANDS AND DEVICES ON THE DASHBOARD OF VEHICLES

The first example regards a classification of the ergonomics, the commands and devices on the dashboard of three automobiles: Dacia 1310 L (year 1999), Daewoo Cielo (year 1993) and VW Jetta (year 1985). This example has a purely demonstrative purpose.

Setting the criteria:

1. quantity of information given by the digital displays;
2. quantity of perception (on the whole) of the analogical displays;
3. quality of perception (on the whole) of the YES/NO type displays;
4. existence and quality of the displays given by the fuel limit display;
5. existence of parasitic reflections of the board lights;
6. visibility of the clock;
7. existence and visibility of the oil pressure indicator;
8. comfort of the setting of the clock;
9. comfort of manipulating the radio;
10. comfort of setting the reset kilometre flow;
11. position of the honk;
12. ease of use of the air conditioning commands;
13. board lightening solution;
14. position of the ashtray and lighter;
15. setting of the intensity of the lightening of commands;
16. sobriety;
17. clarity of symbols.

Establishing the weight factor for each criterion:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Points	Level	γ_i
1	1/2	0	0	0	1	1	0	1	0	0	0	0	0	1	0	0	0	4,5	14	0,56
2	1	1/2	1	0	1	0	1/2	1	0	1	0	1	1/2	1	1/2	1	0	10	6,5	2
3	1	0	1/2	0	1	1	0	1	1	1	0	1/2	1/2	1	1	1/2	0	10	6,5	2
4	1	1	1	1/2	1	0	1/2	1	1	1	1/2	1	1/2	1	1	1/2	1/2	12	3	3,08
5	0	0	0	0	1/2	0	0	1	0	1/2	0	0	0	1	0	0	0	3	15	0,33
6	0	1	0	1	1	1/2	0	1	0	1	0	1/2	1/2	1	1	1	1/2	9	10	1,6
7	1	1/2	1	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	14	2	4,2
8	0	0	0	0	0	0	0	1/2	0	1/2	0	0	0	0	0	1	0	2	16	0,18
9	1	1	0	0	1	1	0	1	1/2	1	0	1/2	1	1	1	1	1	11	4	2,62
10	1	0	0	0	1/2	0	0	1/2	0	1/2	0	0	0	1	1/2	1/2	0	4,5	13	0,62

11	1	1	1	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	15,5	1	5,41
12	1	0	1/2	0	1	1/2	0	1	1/2	1	0	1/2	1	1	1	1	1	10	6,5	2
13	1	1/2	1/2	1/2	1	1/2	0	1	0	1	0	0	1/2	1	1	1/2	1/2	9,5	9	1,79
14	0	0	0	0	0	0	0	1	0	0	0	0	0	1/2	0	0	0	1,5	17	0,09
15	1	1/2	0	0	1	0	0	1	0	1/2	0	0	0	1	1/2	0	0	5,5	12	0,81
16	1	0	1/2	1/2	1	0	0	0	0	1/2	0	0	1/2	1	1	1/2	0	6,5	11	1,03
17	1	1	1	1/2	1	1/2	0	1	0	1	0	0	1/2	1	1	1	1/2	10	6,5	2

According to each criterion each variant was rewarded with the following grades N_i:

	Dacia 1310 L	**Daewoo Cielo**	**VW Jetta**
Criterion	N_i	N_i	N_i
1	5	5	3
2	8	8	7
3	6	3	10
4	8	1	1
5	7	8	9
6	4	6	8
7	1	5	9
8	8	3	10
9	1	5	8
10	4	9	9
11	4	9	6
12	6	6	8
13	7	7	9
14	7	3	9
15	1	1	6
16	2	8	6
17	4	7	7

Regarding the consequence of the weight factor of each criterion, the table above is filled by amplifying the marks (on the rows) with the importance coefficient getting the following values:

		Dacia 1310 L		**Daewoo Cielo**		**VW Jetta**	
Crt.	γ_i	N_i	$N_i \times \gamma_i$	N_i	$N_i \times \gamma_i$	N_i	$N_i \times \gamma_i$
1	0,56	5	2,82	5	2,82	3	1,69
2	2	8	16	8	16	7	14
3	2	6	12	3	6	10	20
4	3,08	8	24,67	1	3,08	1	3,08
5	0,33	7	2,33	8	2,67	9	3
6	1,6	4	6,4	6	9,6	8	12,8
7	4,2	1	4,2	5	21	9	37,8
8	0,18	8	1,45	3	0,55	10	1,82
9	2,62	1	2,62	5	13,08	8	20,92
10	0,62	4	2,46	9	5,54	9	5,54
11	5,41	4	21,65	9	48,71	6	32,47

12	2	6	12	6	12	8	16
13	1,79	7	12,55	7	12,55	9	16,14
14	0,09	7	0,62	3	0,27	9	0,8
15	0,81	1	0,81	1	0,81	6	4,86
16	1,03	2	2,06	8	8,23	6	6,17
17	2	4	8	7	14	7	14
Final classification			**132,64**		**176,9**		**211,1**

2.2. LIFTING JACK FOR A NEW TYPE OF VEHICLE

A second example regards the use of the multi-criteria analysis (only the assessing of the weight factors for the criteria) in an innovating way for choosing the type of lifting jack for a new type of vehicle. Mention is that such a product doesn't exist yet, but with the help of the multi-criteria analysis, the product specifications can be accurately put together.

Establishing the criteria:

1. the best folding possibility;
2. manufacturing cost;
3. amount of effort;
4. body position of the user;
5. modality of attachment to the vehicle;
6. possibility of use on other cars;
7. weight;
8. the extend to which the fold down lifting jack affect the space in the trunk;
9. stability with the car lifted;
10. stability during the lifting;
11. functionality of the accessories;
12. necessity or absence of folding instructions;
13. accessibility to the folded lifting jack.

Establishing the weight factor for each criterion:

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Points**	**Level**	γ_i
1	1/2	0	0	1/2	1/2	1	1/2	1	0	0	1	1/2	0	5,5	8	1,11
2	1	1/2	0	0	1	1	1	1	0	0	1	1	0	7,5	5	1,91
3	1	1	1/2	1	1	1	1/2	1	0	0	1	1	0	9	4	2,6
4	1/2	1	0	1/2	0	0	0	0	0	0	0	0	0	2	12	0,24
5	1/2	0	0	1	1/2	1	1	1	0	0	1/2	1	0	6,5	6,5	1,44
6	0	0	0	1	0	1/2	0	0	0	0	0	0	0	1,5	13	0,11
7	1/2	0	1/2	1	0	1	1/2	1	0	0	1	1	0	6,5	6,5	1,44
8	0	0	0	1	0	1	0	1/2	0	0	1	1	0	4,5	9	0,83
9	1	1	1	1	1	1	1	1	1/2	1	1	1	1	12,5	1	5,54
10	1	1	1	1	1	1	1	1	0	1/2	1	1	1	11,5	2	4,4
11	0	0	0	1	1/2	1	0	0	0	0	1/2	1	0	4	10	0,67
12	1/2	0	0	1	0	1	0	0	0	0	0	1/2	0	3	11	0,44
13	1	1	1	1	1	1	1	1	0	0	1	1	1/2	10,5	3	3,53

2.3. ANALYSIS OF EXTERIOR SIGNBOARDS

Considering the comparative analysis of the design (building a classification) of several signboard models, establishing and weighting the criteria might be similar with the following.

Establishing the criteria:

1. clearness degree;
2. colour concurrence;
3. surface-colour correlation;
4. manufacturing cost;
5. degree of visibility from a distance;
6. illuminating possibility and visibility in the dark;
7. degree to which it reflect the business of the company;
8. harmony between geometrical proportions;
9. wind resistance;
10. degree to which it attracts attention.

Establishing the weight factor for each criterion:

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Points**	**Level**	γ_i
1	1/2	1	1	1	1	1	1/2	1	1/2	1/2	8	1,5	4,6
2	0	1/2	1/2	0	0	1	0	1/2	0	0	2,5	8,5	0,48
3	0	1/2	1/2	0	1/2	1	0	1/2	0	1/2	3,5	7	0,95
4	0	1	1	1/2	0	1/2	0	1	1/2	1/2	5	5,5	1,63
5	0	1	1/2	1	1/2	1/2	0	1	0	1/2	5	5,5	1,63
6	0	0	0	1/2	1/2	1/2	0	1	0	0	2,5	8,5	0,48
7	1/2	1	1	1	1	1	1/2	1	1/2	1/2	8	1,5	4,6
8	0	1/2	1/2	0	0	0	0	1/2	0	0	1,5	10	0,17
9	1/2	1	1	1/2	1	1	1/2	1	1/2	1/2	7,5	3	3,82
10	1/2	1	1/2	1/2	1/2	1	1/2	1	1/2	1/2	6,5	4	2,77

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