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THE METHODOLOGY OF MULTIPLE CRITERIA DECISION MAKING FOR SELECTING THE REFRIGERATION SYSTEM OF GASTRONOMIC FURNITURE

Summary

The growing request for refrigeration gastronomic furniture make necessary to functional and correct select the refrigeration unit. Unfortunately, it is not impossible just indicate one best solution. The best solution can be chosen for a specific user, taking into account the specific requirements of the product. The multiple criteria choice procedure presented the article may be used to implement such undertaking. In addition, the available methods used for multiple criteria decision making are presented, and one of them is selected for the selected decision problem. Based on real values and criteria, the methodology was presented and a multiple criteria analysis was carried out to support the final selection.
Keywords*: multiple criteria decision making, refrigeration system, gastronomic furniture*

METODYKA WIELOKRYTERIALNEGO WSPOMAGANIA PODEJMOWANIA DECYZJI W ZASTOSOWANIU DO WYBORU UKŁADU CHŁODNICZEGO MEBLI GASTRONOMICZNYCH

Streszczenie

Rosnące zapotrzebowanie na chłodnicze mebla gastronomiczne, powoduje konieczność sprawnego i prawidłowego wyboru zastosowanego urządzenia chłodniczego. Niestety nie można wskazać tylko jednego najlepszego rozwiązania. Rozwiązanie najkorzystniejsze można dobrać dla konkretnego użytkownika uwzględniając szczegółowe wymagania dotyczące wyrobu. Do realizacji tego przedsięwzięcia może być wykorzystana procedura wielokryterialnego wyboru przedstawiona w niniejszym artykule. Ponadto przedstawiono dostępne metody wykorzystywane do oceny wielokryterialnej, oraz dokonano wyboru jednej z nich dla wybranego problemu decyzyjnego. Opierając się o rzeczywiste wartości oraz kryteria, zaprezentowano metodykę oraz przeprowadzono analizę wielokryterialną wspomagającą dokonanie ostatecznego wyboru.
Słowa kluczowe*: wielokryterialne wspomaganie decyzji, układ chłodniczy, meble gastronomiczne*

1. Introduction

Operational research as a field of science offers, among others supporting decision making by the analyst using such tools as multiple criteria decision making or multiple criteria decision support [1]. Multiple criteria decision making methods are used to solve completed decisions that require unclear and sometimes contradictory responses. For this reason, it becomes impossible to get a specific answer to the question. Therefore, from a range of individual solutions, select the ones that best suit the preferences. The decision support tool will allow enable approximate the intended purpose, that is the final evaluation of refrigeration system.

In the literature, the most common division of problems related to decision support is the division into three classes [1, 2]:

– selection problems, where the decision maker is tasked with choosing one variant among many categories,

– problems of ordering, where the decision maker is supposed to organize the set of actions according to a different action (individual actions can be comparable with each other or can be incomparable),

– problems of classification, where, in accordance with the previously adopted assumptions, the decision maker divides the variants into parts.

Among the various methods of multiple criteria decision support, two basic approaches are distinguished - American and French [2]. The individual methods of the approaches mentioned differ in the way they operate on criteria that can not be directly compared to each other. As a result of different views, analysis and assessment of decision options are also conducted in a different way. As an example of the American approach, the following methods can be used [3, 5]: AHP, SMART, SAW, MUZ, UTA. The second approach refers to French theory, where the classification of incomparable decision making variants is allowed. An example of the above theory can be the following methods [3, 6]: Promethee, group of methods Electre. There is also a third approach, which is a combination of the two previous theories, where the methods can be an example [3]: Pragma, Idra, Mappac.

Currently, for practical reasons, multiple criteria decision support is often used. It is important that the method is correctly chosen in terms of the nature of the problem.

2. Defining the problem

While solving the main task, which is the development of a refrigeration system design for gastronomic furniture using natural refrigerants, the following decision problem has been defined: how to choose a refrigeration system for gastronomic furniture to ensure maximum satisfaction of the device recipient. Considering the detailed task formulated in this way, it was assumed that the task may be included in the problems of ordering variants.]

3. Choosing the method of multiple criteria decision support

During the initial analysis of the available methods, three methods were selected that can be used to conduct the analysis for a specific decision problem: SAW, AHP, Electre III. Each of the selected methods has its advantages and disadvantages, which are presented in Table 1.

Due to the presented advantages and disadvantages of selected methods of multiple criteria decision support and from the point of view of accepted selection criteria, it was considered that the best choice is the choice of method SAW (Simple Additive Weighting Method).

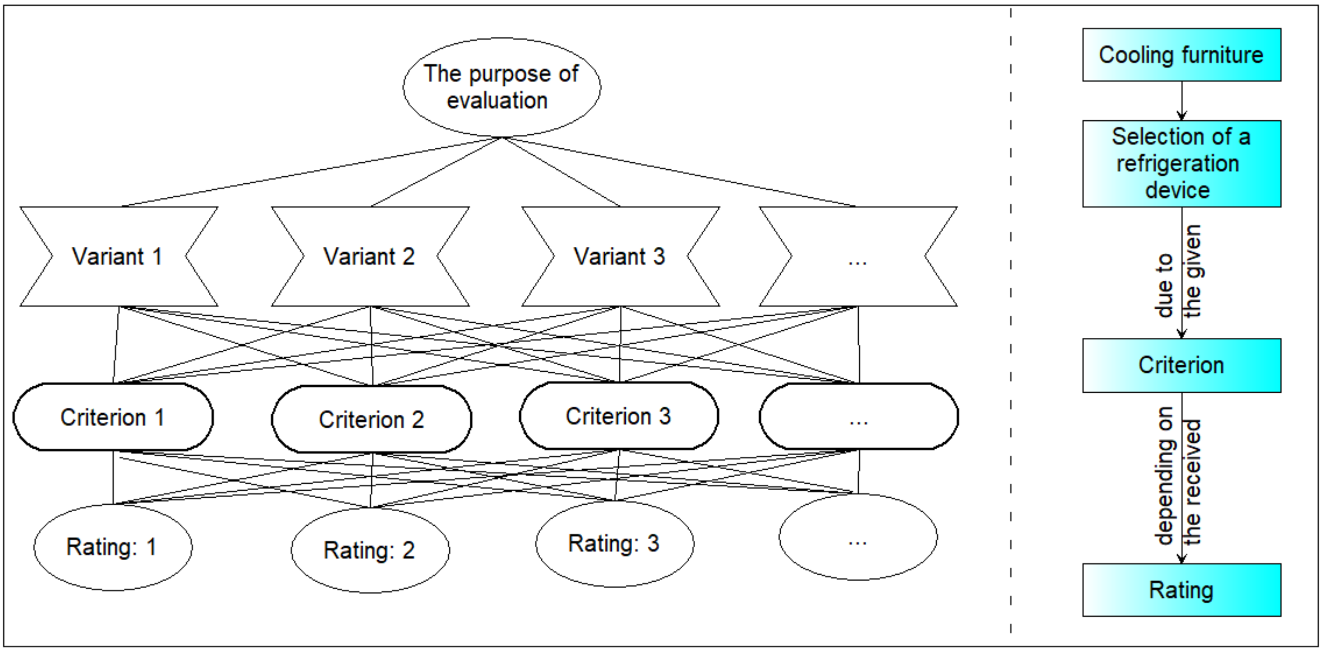
4. Selection and definition of decision criteria

In order to perform a multiple criteria assessment of selected refrigeration furniture, decision criteria for refrigerated furniture were selected. Among the selected criteria there are those that can be easily quantified but there are also such criteria that can not be quantified. Non-numerical criteria should be presented in a descriptive way and then quantified in order to be able to compare and evaluate the criteria among themselves. Fig. 1 presents a hierarchical procedure for choosing a variant.

After the analysis, it was considered that the most representative way of presenting the value of criteria that can not be quantified can be made by presenting them on a five-point scale. Value 5 means the highest rating, while the value 1 is the lowest.

Table 1. Comparison of selected methods of multiple criteria decision support [3, 4, 5, 6]
Tab. 1. Porównanie wybranych metod wielokryterialnego wspomagania podejmowania decyzji [3, 4, 5, 6]

	SAW	AHP	Electre III
Advantages	– simplicity and intuitiveness in modeling the decision maker's preferences, – there is a matrix of normalized ratings, – transformation of the multiple criteria problem into single criteria problem,	– the conformity of assessments is controlled by the coefficient of inconsistency, – the application of subcriteria is possible directly, – orderly way of presenting the task,	– it is possible to take into account non comparable variants, – it is possible to choose preferences in relation to each criterion, – assessed in accordance with actual conditions,
Disadvantages	– subjective way of determining criteria weights, – the need to convert variants (to maximize or minimize problems), – problem in choosing the right weight value for individual criteria,	– unfavorable ratio of the number of criteria to the time the model was created, – the method assumes the scale of preference ratings from 1 to 9 - this scale size in the described case is difficult to implement, – it is possible to easily introduce inconsistencies in the preferences model,	– quite difficult to orientate the requirements, – only indirect application of subcriteria, – in the final ranking there is no possibility of insight into the distance between particular variants.



Source: own study / Źródło: opracowanie własne

Fig. 1. Hierarchical procedure for choosing a variant
Rys. 1. Hierarchiczna procedura wyboru wariantu

In Table 2 explains the reasoning of the rating scale.

Table 2. A five-level evaluation scale of criteria
Tab. 2. Pięciostopniowa skala ocen kryteriów

Quantitative description	Quality description of the solution
1	The worst
2	Worse
3	Average
4	Good
5	Very good

Source: own study / Źródło: opracowanie własne

The selected decision criteria are presented below:
1) the investment cost [PLN],
2) operating costs [PLN/month],
3) COP coefficient [-],
4) way of removing heat from the condenser,
5) noise [dB],
6) impact on the natural environment (in accordance with the applicable standard [7]),
7) brand reputation.

5. Execution the evaluation

Table 3 is the input matrix of solutions for multiple criteria evaluation. Values for easily measurable criteria can be obtained, for example, from the manufacturer's data. On the other hand, the values of the hard-to-measure criteria were assessed using the method adopted in Table 2 rating scale.

In Table 4 shows the average degrees of validity for individual criteria. The degrees of importance have been subjectively selected by the authors of the work in accordance with the suggestion of furniture manufacturers and customer preferences.

Table 4. Scales the main criteria
Tab. 4. Wagi kryteriów głównych

Criterion	Validity
1	0.12
2	0.2
3	0.25
4	0.1
5	0.16
6	0.12
7	0.05

Source: own study / Źródło: opracowanie własne

In order to accept the smallest values describing the considered criteria as the best (the smaller the value, the better solution), transform the Table 3 to the matrix of form *P* according to equation (1). You should convert only those data which before the transformation are not given in this form.

$$P = \frac{1}{a_{ij}} \tag{1}$$

where:
a_{ij} – means the value of the *i*-th variant of the *j*-th criterion.

Table 5. Table of matrix *P*
Tab. 5. Tabela macierzy P

$[P]=$

7200	1320	0.53	0.25	49	0.2	0.20
6400	970	0.59	0.2	52	0.2	0.25
8500	1100	0.49	0.25	45	0.2	0.33

Source: own study / Źródło: opracowanie własne

In the next step, the values of the normalized matrix *P** should be determined, according to the equation (2).

$$P_{ij}^{*} = \frac{P_{ij}}{\sqrt{\sum_{i=1}^{m} P_{ij}^{2}}} \tag{2}$$

where:
$i = 1\ldots m$; $j = 1\ldots n$; (m – quantity of variants, n - quantity of criteria)

Table 6. Table of normalized matrix *P**
*Tab. 6. Tabela macierzy znormalizowanej P**

$[P^*]=$

0.560	0.669	0.570	0.615	0.580	0.577	0.433
0.498	0.492	0.634	0.492	0.616	0.577	0.541
0.662	0.557	0.523	0.615	0.533	0.577	0.721

Source: own study / Źródło: opracowanie własne

In a further stage, validity should be taken into account in relation to the given criteria. A list of variants, criteria and weights is presented in Table 7.

Table 3. Input matrix for the evaluation of multiple criteria
Tab. 3. Macierz wejściowa dla oceny wielokryterialnej

	Criterion 1	*Criterion 2*	*Criterion 3*	*Criterion 4*	*Criterion 5*	*Criterion 6*	*Criterion 7*
	the investment cost [PLN]	operating costs [PLN/month]	COP coefficient [-]	way of removing heat from the condenser	noise [dB]	impact on the natural environment	brand reputation
Variant 1	7200	1320	1.88	4	49	5	5
Variant 2	6400	970	1.69	5	52	5	4
Variant 3	8500	1100	2.05	4	45	5	3

Source: own study / Źródło: opracowanie własne

Table 7. Table of normalized matrix of input solutions P^* with scales

Tab. 7. Tabela macierzy znormalizowanej wejściowych rozwiązań P^* z przypisanymi wagami

	Criterion 1	*Criterion 2*	*Criterion 3*	*Criterion 4*	*Criterion 5*	*Criterion 6*	*Criterion 7*
Variant 1	0.560	0.669	0.570	0.615	0.580	0.577	0.433
Variant 2	0.498	0.492	0.634	0.492	0.616	0.577	0.541
Variant 3	0.662	0.557	0.523	0.615	0.533	0.577	0.721
Validity q	**0.12**	**0.2**	**0.25**	**0.1**	**0.16**	**0.12**	**0.05**

Source: own study / Źródło: opracowanie własne

Table 8. The results of the multiple criteria evaluation using the simple additive weighting method

Tab. 8. Wyniki oceny wielowariantowej przy wykorzystaniu metody sumy ważonej

	Criterion 1	*Criterion 2*	*Criterion 3*	*Criterion 4*	*Criterion 5*	*Criterion 6*	*Criterion 7*	**SUM**
Variant 1	0.0673	0.1338	0.1425	0.0615	0.0928	0.0693	0.0216	**0.5888**
Variant 2	0.0598	0.0983	0.1585	0.0492	0.0985	0.0693	0.0270	**0.5607**
Variant 3	0.0794	0.1115	0.1307	0.0615	0.0853	0.0693	0.0361	**0.5737**

Source: own study / Źródło: opracowanie własne

In order to get a solution to the multiple criteria problem, the value of each criterion of a given variant should be multiplied by the validity assigned to it according to the equation (3). The results of the multiple criteria evaluation using the simple additive weighting method were placed in Table 8.

$$V_{ij} = P_{ij}^* \cdot q_{ij} \qquad (3)$$

where:

P_{ij}^* – the normalized value of the *i*-th variant, the *j*-th criterion,

q_{ij} – validity of the *i*-th variant, *j*-th criterion.

According to the initial assumptions for the mentioned problem, the lowest value of the sum means choosing the best variant from the presented ones. Therefore, according to the assessment, variant 2 should be taken into consideration first with the result of 0.5607, then variant 3 with the result of 0.5737, and finally variant 1 should be considered with the result of 0.5888.

6. Summary

There are many different methods to support the decision-making process at various stages of designing cooling installations. For the given case, the weighted sum method was a useful method, which enabled to obtain an unambiguous answer. The presented application streamlines the decision making process by the decision maker. However, it is worth noting that it does not make a choice as a decision maker but is only meant to serve as a hint for further analysis. The tool used enables a free way to conduct the analysis thanks to the possibility of its extension and modification.

7. References

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