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A NEW MODEL FOR EVALUATION AND SELECTION OF RECYCLING TECHNOLOGIES

Abstract: *The problem of evaluation and selection of recycling technologies is very important from the economic aspect and the aspect of environmental protection. In this paper we developed a new model for evaluation of recycling technology respecting multiple criteria, simultaneously, as well as their weights. The relative importance of the criteria was set as the task of group decision-making, and is set using matrices The comparison pairs. Rank of recycling technology is determined by using a modified TOPSIS method.*
Key Words: *technology of recycling, group decision making, AHP, TOPSIS*

1. INTRODUCTION

The processes of globalization and the increased consumption of resources has led to the creation of high amount of waste which led to a large negative impact on man and the environment. This phenomenon is in many countries caused by the need to limit the consumption of natural resources. On the other hand, population growth at global level and application of concepts that put into focus the needs and desires of the customer has led to increased consumption of products. All these changes have led to the need to develop a system of waste management. In recent decades, people's awareness of recycling has significantly increased. Process management of recycling has become a subject of interest for both researchers and reverse logistics managers alike. The choice of optimal technology of recycling is one of the subproblems of reverse logistics management and is discussed in the literature (Pavlović et al, 2016; Tadić et al, 2015).

A selection of the best technology of recycling is done for each type of waste and depends on several criteria. Therefore, the problem discussed can be set as a task multiple-criteria analysis. This can be defined as the main contribution of the paper. Assessment of criteria importance is set as a task of group decision making, and can be designated as a second contribution of the paper.

The paper is organized as follows. In Section two given is the problem setting. The third section gives the proposed algorithm. In the fourth section are given conclusions and directions for further research.

2. PROBLEM SETTING

In this section is given a detailed setting of the considered problem. Also used notation is precisely and clearly explained.

Step 1. In the decision-making process participate many decision makers that make the expert team. The expert team consists of managers who come from the recycling center (chief manager, quality manager and manager of environmental protection) and of stakeholders coming from local authorities. Formally expert team presents a set of indices where E is the total number of experts and e, e = 1, .., E is the index for expert.

Formally, possible recycling technologies are presented by a set where I is the total number of possible recycling technologies. The index of recycling technologies is designated as i, i = 1, .., I. The set elements are determined based on the knowledge and experience of experts on the recycling of certain types of waste, the recommendations that can be found in the literature that respect the technology level of considered recycling center. It should be noted that if the recycling center is to recycle more wastes, it is necessary for each type of waste to define set of possible recycling technologies.

Step 3. The criteria according to which are evaluated recycling technologies is defined by the expert team. Formally, these criteria constituted are presented as set wherein K is the total number of criteria, and k, k = 1, .., K is the index of the criterion. In the literature there are recommendations on how to define the criteria for assessing recycling technologies. Only economic criteria can be considered, such as costs that occur in the application of technology, the quality of the obtained recyclate, sustainable development of the environment in which the recycling center is located, the ratio of the price of recycled materials and the prices of raw materials, etc. In recent decades due to the increasing importance of environmental protection environmental criteria are increasingly being taken into account in the evaluation and selection of recycling technologies. SInce recycling has a wider social significance, it is important to consider the social criteria such as the quality of life of the population of the region, the level of employment, employment of people belonging to vulnerable social groups, job security and others.

Step 4. The relative importance of the criteria by which are recycling technologies evaluated for one type of waste do not have the same importance. It can be assumed that closer to the human way of thinking the relative importance of the criteria need to be presented by comparison of pairwise matrix (Pavlovic et al, 2016). The elements of this matrix are estimated by decision makers. Policy makers expressed their estimates using a standard scale measures (Saaty, 1980). Have the relative importance of the criteria k, k = 1, ., K by criteria $k', k, k' = 1,..,K; k \neq k'$ expressed as $W_{kk'}^{e}, e = 1,..,E$ for every decision maker.

Step 5. A realistic assumption that decision makers do not have the same importance in the issue of the importance of evaluation criteria for the selection of the best recycling technology can be introduced. The importance of decision-making has been marked as $q_e, e = 1,..,E$ and determined on the basis of experience of best practice. For example, the greatest importance has the general manager of a recycling center and a representative of the local government which is responsible for the economic development of the region. Recently, a representative of the local government which is responsible for the harmonization of national legislation in the field of recycling with the European Union has an increasing role in decision making. Aggregation of reviews of decision makers into a single score, inside the introduced presumptions, can be accomplished by using the operator difficulty in aggregation (OWA) (LIT).

Step 6. Pairwise matrix comparisons of aggregate relative importance of the criteria is set. Consistency of the matrix is determined by applying the method eigenvector (LIT). If the ratio is greater than 0.1-it is essential that decision makers re-inspect. The values of discussed criteria for each possible recycling technology evaluates the management team. It can be considered that those decisions are made by consensus. Decision makers their assessments map on a standard scale measures. Have's value criteria k, k = 1, .., K for possible strategy for recycling and, i = 1, .., marked as $v_{ik}, i = 1,..,I; k = 1,..,K$.

Step 7. Criteria for evaluating recycling technologies generally can be benefit and cost type (LIT). Criteria of benefit type are defined as follows: the higher the value of the criteria the better, and vice versa. The criteria of cost type define: the lower the value of criteria the better, and vice versa. If this assumption is introduced it is necessary to perform normalization value $v_{ik}, i = 1,..,I; k = 1,..,K$ Using the method of normalizing all values $v_{ik}, i = 1,..,I; k = 1,..,K$ are mapped to the range [0-1], and thus become comparable A value of 0 or a value 1 indicates that the value of criteria k, k = 1, .., K, and for the possible recycling, i = 1, .., I minimum, or maximum, respectively. The normalization may be accomplished by application of various methods which are shown in (Pomerol and Barba-Romeao, 2000). In this paper we used the vector normalization.

Step 8. Using the conventional TOPSIS (LIT) methods a range of possible recycling strategy observed in the recycling center is determined.

Step 9. The decision on the choice of recycling technologies should be based on the resulting range.

3. EXAMPLES OF EMOTIONAL DESIGN

The proposed algorithm can be implemented according to steps that are further shown.

Step 1. Place the pairwise matrix of comparisons of the relative importance of the criteria

$$\left[W^{e}_{kk'}\right]_{KxK}, k,k' = 1,..,K; k \neq k'; e = 1,..,E$$

Step 2. Place the pairwise matrix of comparisons of aggregated relative importance of the criteria:

$$W_{kk'} = \sum_{e=1}^{E} q_e \cdot W^{e}_{kk'}\ k,k' = 1,..,K; k \neq k'; e = 1,..,E$$

so that:

$$\left[W_{kk'}\right]_{KxK}, k,k' = 1,..,K; k \neq k'$$

Step 3. Check consistency of pairwise matrix total aggregate relative importance of criteria:Consistency Index (C.I.) is calculated according to the formula:

C.I.=C.R./R.I.

Wherein C.R. the ratio of consistency which is defined in (Saaty, 1980) and is calculated as

$$C.R. = \frac{\lambda_{max} - K}{K-1}$$

The total number of the discussed criteri as noted above is K and i λ_{max} is the maximum value of pairwise matrix vectors comparing aggregated relative importance of the criteria.

For each dimension of the constructed matrix, the random values are defined and marked as R.I. whose dimensions are displayed in Table 2.1 [2-Paper].

Table 1. RI values depending on the size of the pairwise matrix comparisons

K	3	4	5	6	7	8	9	10	11	12	13	14
R.I.	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57

Calculation of the the maximum value of eigenvector constructed matrix, is calculated through one or more iterations.

By applying the method eigenvector is obtained vector weight criteria

$$w = (w_1,...,w_k,...,w_K),\ k = 1,..,K$$

Weight values are described by ordinal numbers and their sum is equal to one.

Step 4. Determine a normalized value criteria for each possible recycling technology

$$r_{ik}, i = 1,..,I; 1,..,K$$

a) for benefit type

$$r_{ik} = \frac{v_{ik}}{\sqrt{\sum_{i=1}^{I} v_{ik}^2}}, i = 1,...,I; k = 1,...,K$$

b) for cost type

$$r_{ik} = \frac{1/v_{ik}}{\sqrt{\sum_{i=1}^{I} (1/v_{ik})^2}}, i = 1,...,I; k = 1,...,K$$

Step 5. Let the positive ideal solution (PIS) for each criterion is equal to 1. In a similar way, negative ideal solution is determined (NIS) for each criteria and it totals 0.

a) for benefit type

$$r_{ik} = \frac{v_{ik}}{\sqrt{\sum_{i=1}^{I} v_{ik}^2}}, i = 1,...,I; k = 1,...,K$$

Step 6. calculate the removal of every possible technology of recycling PIS, d_i^+ and of NIS, d_i^- :

$$d_i^+ = \sum_{k=1}^{K} (1 - d_{ik}), \; i = 1,\ldots,I$$
,
$$d_i^- = \sum_{k=1}^{K} (d_{ik} - 0), \; i = 1,\ldots,I$$

Step 7. Determine the coefficient approximation which joins every possible recycling technology and, i=1,..,I, c_i :

$$c_i = \frac{d_i^-}{d_i^- + d_i^+}, \; i=1,..,I$$

Step 8. We sort calculated values in descending order. Recycling Technology which is the first in the range is the best with respecting all considered criteria and their weights. Similarly, it is concluded that the technology of recycling which is affiliated to the minimum value of the coefficient approximation is the worst

Step 9. According to obtained rank, the expert team makes a decision which recycling technologies should be applied at the recycling center for the given type of waste.

4. CONCLUSION

Based on the results of the best practices of developed countries it can be concluded that recycling different types of waste have a large impact on both the economy and the sustainable development of observed country. Therefore, it can be said that the management and improvement of the recycling process leads to increasement of business efficiency and recycling centres and affect the economic development of the country. This is a significant problem in developed countries and in developing countries. Evaluation and selection of recycling technologies, which was discussed In this work, is one of the most important problems in the supply chain management of reverse logistics.

The criteria for assessing recycling technologies are defined by the expert team. So it can be said that determining the relative importance of the criteria was set as the task of group decision making. As members of the expert team dont have equal importance in the process of making their opinions aggregation of their opinions into a single evaluation is performed by using OWA operators.

It is closer to the human way of thinking to assess the importance of each set of criteria than using direct assessment methods. By applying the method of the eigenvector can be obtained weights vector of the decision criteria. The authors believe that the values of the PIS and NIS are determined according to a specific concept of the veto (analog LIT). Introduced assumption significantly simplify calculation of the possible removal of recycling technology of the considered criteria. So it can be said that a modification of the conventional TOPSIS method is a contribution to this work.

Ranking the possible recycling technology is carried out using a modified TOPSIS methods. Based on the obtained rank expert team makes a decision on the choice of recycling technologies. The best recycling technology is the one that is first in the rank. So it is concluded that this technology should be applied in the process of recycling waste in the studied type of treated recycled Center. However, for some reason, economic, social or technical impossibility, due to the marked recycling technology implementation at the recycling center, the expert team may decide that the best possible technology of recycling is located on the second or third place in the rank. Indeed, if policymakers decide on the basis of the rank obtained in an exact manner of their decisions is more accurate because it is less burdened by subjective views.

The proposed model can be used in all recycling centers and for each type of waste. This can be considered as one of the advantages of the modified TOPSIS method developed in this paper. Any changes that occur in a number of criteria or the number of recycling technology as well as changes in the relative importance of the criteria can be quickly and easily implemented in the developed model.

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