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THE FUZZY MODEL FOR EVALUATION WASTE IN PRODUCTION PROCESS OF RECYCLING DEVICE

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Abstract. *The aim of this paper is to explain a model for evaluating effects of different waste types which are formed in the production process into environment. The relative importances of identified waste types are different and are given by expert's assessment. Their assessments are described by linguistic expressions which are modelled by triangular fuzzy numbers. The aggregation of the individual opinions into group consensus is performed by using the fuzzy ordered weighted averaging operator. The elements of decision matrix can be calculated as product of the the aggregated relative importance of considered waste type and its value. The rank of identified waste types is given by PROMETHEE method. The effect of considered waste types into environment corresponding to the given rank. The proposed method is illustrated by example with real life data.*

Key words: *Environment, Waste, fuzzy group decision making, PROMETHEE.*

1. INTRODUCTION

Environment protection management is an area of industrial engineering that has been a very popular field of research in the terms of science and practice in last decade. Recycling management enable the development and sustainability of the company over time. According to evidence data, about 70% different waste types can be recycled. The solution of this problem can be found by applying recycling processes. It can be said that recycling processes have effect to economic, environment and energetic domains.

Recycling process can be defined as processing materials which can be used for production of different raw materials. The basic assumptions of recycling process management are: R- reduce, R-reuse, and recycle.

These are many waste types. In this paper, the focus of authors are waste which are created in the production process.

The evaluation of the effect to of the different waste types into environment can be solved by using Life Cycle Assessment (LCA) which is defined in the ISO 14040:2006, SRPS ISO 14040: 2008.

In [1] it is supposed that the considered problem can be stated as multi-criteria optimization task. In this paper PROMETHEE method [2]. There are six preference types which are defined in the PROMETHEE. Choosing preference types is based on experience and knowledge of decision makers [3].

Ranking factors which effect to environment is performed by using the PROMETHEE in ([4], [5]).

Comparing to papers which can be found in the literature, the proposed model has the some differences which can be denoted as advantages. By using LCA method, the wastes which formed in the production process are identified. The three environment elements are considered: ground, air and water. It is assumed that these elements have equal importance. Determining the relative importance of the identified wastes into environment elements is stated as fuzzy group decision making problem. The waste values are estimated by experts. Their estimates are based on the evidence data.

The paper is organized in the following: The short survey of the respecting literature is presented in Section 1. The problem statement is given in Section 2. Section 3 shows the proposed Algorithm. The proposed model is illustrated by real life data and presented in Section 4. The Conclusion is given in Section 5.

2. PROBLEM STATEMENT

The production process of recycling device can be decomposed into sub-processes. There are many kinds of waste which can be ensured in considered business process. The list of ensured waste can be defined. Each waste type has an effect into elements of environment (wather, air, ground).

The aim of this paper can be defined as determining waste type which has an highest effect to environment.

In general, waste types can be presented by set $I = \{1,...,i,...,I\}$. The total number of considered waste kinds and the total number of environment elements is denoted as I, and J, respectively. The environment is presented by set $J = \{1,...,j,...,J\}$. The i and j, respectively is index for waste type i, i=1,..,I, and environment element j, j=1,..,J, respectively. The relative importance of waste type i, i=1,..,I into environment element j, j=1,..,J is different.

The management team (quality manager, environment manager, production manager) make estimates of the relative importance of treated uncertainties. The management team uses linguistic expressions instead of precise numbers. It is close to the human thinking. The fuzzy rating of the relative importance of each considered uncertainties at the level each decision maker e, e=1,..,E are modelled by triangular fuzzy numbers (TFNs), $\widetilde{W}_{ij}^{e} = (x;\ l_{ij}^{e}, m_{ij}^{e}, u_{ij}^{e})$, with the lower and upper bounds l_i^e, u_i^e and modal value m_i^e, respectively. These TFNs are:

very low importance - $\tilde{R}_1 = (x;0,0,0.2)$

low importance - $\tilde{R}_2 = (x;0.1,0.3,0.5)$

moderate importance - $\tilde{R}_3 = (x;0.2,0.5,0.8)$

high importance - $\tilde{R}_4 = (x;0.5,0.7,1)$ and

very high importance - $\tilde{R}_5 = (x;0.8,1,1)$.

As mentioned, the production manager groups have unequal importance, so the aggregated values of the relative importance of waste types, and aggregated values of the relative importance of calculated by using the fuzzy ordered weighted averaging operator (FOWA) which is explained in [6]. The FOWA operator is an extension of the ordered weighted averaging (OWA) operator. The relative importance of quality manager, environment manager and production managers are 0.27, 0.48, and 0.25, respectively. By using the moment method [7], the representative scalars w_{ij}, respectively, are given.

The weighted values of waste type at the level of each environment element is calculated as product the aggregated relative importance and assessed value for each environment element j, j=1,..,J. The normalization of elements of decision matrix are given by using the vector normalization procedure [8].

3.0 THE PROPOSED ALGORITHM

The modified PROMETHEE method can be realized by using the following steps:

Step 1. Fuzzy rating of the relative importance of each waste type for each environment element is performed by each decision maker, $\widetilde{W}_{ij}^{e}$, i=1,..,I; j=1,..,J;e=1,…,E

Step 2. Determine to the aggregated value of the relative importance $\widetilde{W}_{ij}$:

$W_{i,j}$ = FOWA ($\widetilde{W}_{ij}^{e}$)

Step 3. Determine the representative scalar, W_{ij} of TFNs $\widetilde{W}_{ij}$, i=1,..,I; j=1,..,J

Step 4. Determine to value of each waste type, i=1,..,I for each environment element j, j=1,..,J, $v_{i,j.}$

Step 5. Construct to the decision matrix D:

$$D = [d_{ij}]_{IxJ}$$

where:

$d_{ij} = W_{ij} \cdot v_{ij}$ is weighted value of waste type I, i=1,..,I for environment element j, j=1,.,J.

Step 6. The normalization of elements of the decision matrix is given by vector normalization procedure:

$r_{i,j} = \frac{d_{i,j}}{\sqrt{(\Sigma_{i=1}^{r} d_{i,j}^{2})}}$, i=1,…,I; j=1,..,J

Step 7. The preference index of each waste type I, i=1,.,I for each environment element j, j=1,.,J is defined as:

- Positive flow:
  $\emptyset_j^+(a_i) = \sum_{m=1}^{I} \Pi(a_{i,} a_m)$

- Negative flow:
  $\emptyset_j^-(a_i) = \sum_{m=1}^{I} \Pi(a_{i,} a_m)$

Step 8. Determine the overall preference flow:

$\emptyset_j(a_i) = \emptyset_j^+(a_i) - \emptyset_j^-(a_i)$, j = 1,....., J

Step 9. Rank of considered waste types is determined with respects to all environment elements and their weights.

4.0 ILLUSTRATIVE EXAMPLE

In this Section, the proposed Algorithm is illustrated by real-life data.

The indetified waste type are: oil (i=1), dizel (i=2), organic waste (i=3), synthetic waste (i=4), metal wate (i=5), plastic waste (i=6), rubber waste (i=7) and cleaners (i=8).

Respecting to literature data, it is assumed that unit value of the metal waste is 0.8, the placstic waste is 0.06, rubber waste is 0.04, and other waste types is 0.1.

By using the proposed Algorithm (Step 1) the relative importance og each waste type i, i=1,..,I for

each environment element j, j=1,..,J are assessed and shown in Table 1.

Table 1. Fuzzy rating of the relative importance of each waste type for each environment element

k=1			k=2			k=3		
Q	E	P	Q	E	P	Q	E	P
$\widetilde{R_3}$	$\widetilde{R_2}$	$\widetilde{R_2}$	$\widetilde{R_4}$	$\widetilde{R_3}$	$\widetilde{R_1}$	$\widetilde{R_2}$	$\widetilde{R_1}$	$\widetilde{R_1}$
$\widetilde{R_4}$	$\widetilde{R_4}$	$\widetilde{R_1}$	$\widetilde{R_5}$	$\widetilde{R_5}$	$\widetilde{R_3}$	$\widetilde{R_3}$	$\widetilde{R_3}$	$\widetilde{R_1}$
$\widetilde{R_2}$	$\widetilde{R_2}$	$\widetilde{R_1}$	$\widetilde{R_3}$	$\widetilde{R_1}$	$\widetilde{R_1}$	$\widetilde{R_1}$	$\widetilde{R_1}$	$\widetilde{R_1}$
$\widetilde{R_3}$	$\widetilde{R_4}$	$\widetilde{R_4}$	$\widetilde{R_4}$	$\widetilde{R_4}$	$\widetilde{R_3}$	$\widetilde{R_2}$	$\widetilde{R_3}$	$\widetilde{R_3}$
$\widetilde{R_2}$	$\widetilde{R_3}$	$\widetilde{R_4}$	$\widetilde{R_1}$	$\widetilde{R_1}$	$\widetilde{R_3}$	$\widetilde{R_2}$	$\widetilde{R_4}$	$\widetilde{R_5}$
$\widetilde{R_3}$	$\widetilde{R_4}$	$\widetilde{R_4}$	$\widetilde{R_2}$	$\widetilde{R_3}$	$\widetilde{R_3}$	$\widetilde{R_1}$	$\widetilde{R_1}$	$\widetilde{R_2}$
$\widetilde{R_4}$	$\widetilde{R_5}$	$\widetilde{R_3}$	$\widetilde{R_1}$	$\widetilde{R_2}$	$\widetilde{R_1}$	$\widetilde{R_3}$	$\widetilde{R_4}$	$\widetilde{R_3}$
$\widetilde{R_3}$	$\widetilde{R_2}$	$\widetilde{R_2}$	$\widetilde{R_5}$	$\widetilde{R_4}$	$\widetilde{R_4}$	$\widetilde{R_4}$	$\widetilde{R_3}$	$\widetilde{R_3}$

The aggregated values of the realtive importnace of treated importance are given by the proposed Algorithm (Step 2 to Step 3). The proposed procedure is illustrated further. Consider the gumeni otpad (i=7). The relative importance of this easte type is assessment by management team. The aggregated value of the treated waste type is:

$\widetilde{W_{71}} = 0.27.\widetilde{R_4} + 0.48.\widetilde{R_5} + 0.25.\widetilde{R_3}$=(x; 0.569, 0.794, 0.950)
such as $W_{71} = 0.782$

By appying the proposed Algorithm (Step 4 to Step 5) decision matrix is constructed.

Table 2 The weighted decision matrix

0.0354	0.0429	0.0081
0.0525	0.0750	0.0375
0.0225	0	0
0.0886	0.065	0.0446
0.3968	0.100	0.5288
0.0388	0.0268	0.0045
0.0318	0.0058	0.0197
0.0354	0.0781	0.0365

The normalized decision matrix is calculated and shown in Table 3 (by analogy Step 6 of the proposed Algorithm).

Table 3 The normalized decision matrix

0.0849	0.2539	0.0152
0.1261	0.4439	0.0703
0.0541	0	0
0.2139	0.3847	0.0836
0.9523	0.5919	0.9908
0.0931	0.1586	0.0084
0.0667	0.0343	0.0369
0.0854	0.4622	0.0683

The preference index for each environment element j, j=1,..,3 is calculated by using the proposed Algorithm (Step 7):

Table 3 The preference index for k=1

									$\emptyset_j^-(a_i)$
	0	1	0	0	0	0	0	0	**1**
	1	0	1	0	0	1	1	1	**5**
	0	0	0	0	0	0	0	0	**0**
	1	1	1	0	0	1	1	1	**6**
	1	1	1	1	0	0	0	0	**4**
	1	0	1	0	0	0	1	1	**4**
	0	0	1	0	0	0	0	0	**1**
	0	0	1	0	0	0	1	0	**2**
$\emptyset_j^+(a_i)$	**3**	**3**	**6**	**1**	**0**	**2**	**4**	**3**	

Table 4 The preference index for k=2

									$\emptyset_j^-(a_i)$
	0	0	1	0	0	1	1	0	**3**
	1	0	1	1	0	0	0	0	**3**
	0	0	0	0	0	0	0	0	**0**
	1	0	1	0	0	1	1	0	**4**
	1	1	1	1	0	1	1	1	**7**
	0	0	1	0	0	0	1	0	**2**
	0	0	1	0	0	0	0	0	**1**
	1	1	1	1	0	1	1	0	**6**
$\emptyset_j^+(a_i)$	**4**	**2**	**7**	**3**	**0**	**4**	**5**	**1**	

Table 5 The preference index for k=3

									$\emptyset_j^-(a_i)$
	0	0	1	0	0	1	0	0	**2**
	1	0	1	0	0	1	1	1	**5**
	0	0	0	0	0	0	0	0	**0**
	1	1	1	0	0	1	1	1	**6**
	1	1	1	1	0	1	1	1	**7**
	0	0	1	0	0	0	0	0	**1**
	1	0	1	0	0	1	0	0	**3**
	1	0	1	0	0	1	1	0	**4**
$\emptyset_j^+(a_i)$	**5**	**2**	**7**	**1**	**0**	**6**	**4**	**3**	

By using the proposed Algorithm (Step 8 to Step 9) the overall preference index and rank of the considered waste is determined and presented in Table 6.

Table 6 The rank of the treated waste in production process

	$\emptyset^+$ -$\emptyset^-$	Rank
i=1	12-6=6	**6**
i=2	7-13=-6	**3**
i=3	20-0=20	**8**
i=4	5-16=-11	**2**
i=5	0-17=-17	**1**
i=6	12-7=5	**5**
i=7	13-5=8	**7**
i=8	7-12=-5	**4**

According to the obtained results it can be said that the highest effect to the environment has the waste which is denoted as metal wate (i=5). It can be concluded that recycling technologies of metal waste should be improved.

5. CONCLUSION

Based on the results of good practice of developed countries is known that well organized and existing of recycling processes have high influence on realization of state development strategy. One of the management problems of recycling domain is environmental protection. The environment elements can be ground, air and water. It is assumed that these elements have equal relative importance. The assessment of waste types into environment may be introduced through identification of waste type, assessment their priorities. The solution of considered problem is obtained in exact way because the solution is less burdened by the subjective judgments of decision makers.

All uncertainties in relative importance of waste types are described by predefined linguistic expressions. Decision makers present their opinion by using linguistic expression in more precise way than by using precise numbers. Linguistic variables are modeled by TFNs which offer a good compromise between its computational ability and accuracy of the results. The aggregation opinions of decision makers into group consensus is performed by FOWA operator. The values of identified waste types are assessed by evidence data.

The rank of the identified waste types with respect to all environment elements is given by applying PROMETHEE method. The highest effect to the environment has waste type which is placed into at the first place in the rank. According to obtained results, the improvement strategies of environmental protection can be defined (one of requirement ISO 9001:2008, and ISO 144000).

Besides the advantages, the proposed model has certain constraints, for instance the number of waste types, available of evidence data, change of number of waste types and/or environment elements, change legal regulations, etc.

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