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EVALUATION OF INFLUENCE RECYCLING DEVICE ON ENVIRONMENT IN PRODUCTION PROCESS PHASE BY TOPSIS METHOD

Abstract: *In this paper a problem of influence assessment of every input variable in the production process of recycling device was considered due to three key elements of environment (water, air and ground). All input variables which are considered in the production process are received by using LCA (**L**ife **C**ycle **A**ssessment) method. The influence of each kind of waste to the each environment element was assessed by modified TOPSIS (**T**echnique for **O**rder **P**reference by **S**imilarity to **I**deal **S**olution) method.*
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1. INTRODUCTION

Last decades, the problem of environmental protection represents an interesting field of research in different spheres: economical, energetic, industrial and etc. Environmental protection represents one of the main task of human society, therefore people are more and more involved in solving this problem. Environmental pollution means not only destruction of natural values and resources it also means future generations deeds destruction.

In production process of different products various kind of waste appeared which have had bad influence to the environment. Each component and the process involved in production of some product have influence to the nature pollution. As well, to make a product, some natural resources have to be used, one of them could be barely renewable. Therefore trend exists to lower the consumption of natural resources.

To determine the level of bad influence of certain elements, which participate in production process, to the environment, throughout their life cycle, many methods have been used. The widest is used LCA method (**L**ife **C**ycle **A**ssessment), used in this paper. To determine quantitatively bad influence of input and output size, made in the production process, on the environment, TOPSIS (**T**echnique for **O**rder **P**reference by **S**imilarity to **I**deal **S**olution) [1] method have been used.

The paper was organised as followed: In Section two the literature review was listed. Problem statement is presented in third section. Developed algorithm of modified TOPSIS method is showed in Section four. Developed method is illustrated with an example where exists data received in real production terms and section five covered it. Discussion and conclusions are represented in Section six.

2. LITERATURE REVIEW

There are not many literature papers in which problem of influence of some waste species to environmental elements is solved by combination of LCA, life cycle assessment, and TOPSIS method. However, there are many papers, where these methods are individually used, or in combination with some other multicriteria optimization methods.

In [2] LCA method for life cycle assessment was applied. All the variables which could affect the environment, every subprocess, are classified, by the author, in the next categories:

- energy input, raw material input, auxiliary input and other physical inputs;
- products, coproducts and waste;
- emission in air, release in water and ground, and
- other environment aspects.

In paper [3] production process and copper recycling life cycle was analyzed. The waste appeared at the end of production process was grouped as followed:

- energy consumption ($\frac{MJ}{kg\ Cu}$),
- global warming effect ($\frac{kg\ CO_2}{kg\ Cu}$),
- acidification ($\frac{kg\ SO_2}{kg\ Cu}$).

TOPSIS method is used in solving many problems. In [4] a problem of ranking transport companies which were registered for dangerous waste transport, was considered. Bank ranking due to multiple criteria, simultaneously, was done by TOPSIS method in [5]. The selection of types of biomass which is used as fuel for boilers is performed by using TOPSIS method [6]. Criteria for assessment considered types of biomass are defined due to fuel characteristics, as if price, fuel availability on Thailand, caloric and transport.

Comparing the papers which could be find in the literature, the model presented in this paper has got certain benefits. The difficulty of criteria on which the assessment is made is an alternative created by fuzzy AHP [7]. In [6] evaluation of criteria difficulty was based on experts evaluations who use direct way of assessment. In the model which is developed in this paper management team performs evaluation of relative importance of every waste type on every environmental element. It is considered that the aggregation of member evaluation of management team into the group consensus is created using operator OWA (Ordered Weighted Aggregation) [8]. The normalization of alternative value can be made using different methods which are presented in [9]. Vector normalization was applied in ([4], [5]). In submitted work linear normalization is used as if it is defined in conventional TOPSIS and [6].

3. PROBLEM STATEMENT

Production process is complicated and can be decomposed in many subprocesses. For every subprocess input and waste which is appeared at the output of every subprocess are identified. The list of waste that represent output of every subprocess within that process is defined. Each of these type of waste influence to the environment (water, air and ground). This paper goal is to determine which type of waste has the biggest influence to the environment.

Types of waste can formally be presented by set $I = \{1,...,i,...,I\}$, where i is index for considered type of waste, and I is the total number of considered type of waste. Every type of waste i, $i = 1,...,I$ has got different relative influence on each environmental element j, $j = 1,...,J$. Environmental element index is marked as j, and J is the total number of environmental elements.

Management team (quality manager, manager for environment protection, production manager) is estimated relative importance of waste types i, $i = 1,...,I$ to the environmental elements j, $j = 1,...,J$.

In this paper the considered problem is presented as if a problem of group decision making. Aggregation of member evaluation of management team into the group consensus is created using different operators such as average value, Delphi method, OWA [8] operator. It is presumed that the management team members have not got the same importance to determine the waste influence, which is created in production process, on environment. Following this assumption, in this paper, the aggregation of individually management team members assessment into the group consensus is created using operator OWA [8]. The importance of manager for quality should be 0,27, for the environment 0,48, and for production manager 0,25.

In the literature a great number of papers could be found where different scale measures are used. The most commonly used is Saaty's [7] measuring scale. It is often used measuring scale [0-1] and school measuring scale [1-5]. In this paper the assumption is introduced in order to use school measuring scale, because only three environmental elements are being considered.

The value of influence each type of waste i, $i = 1,...,I$ on every environmental element j, $j = 1,...,J$, generally can be achieved in two ways. The first way is by measuring and the second way is by assessment. In considered problem it is almost impossible that the value of influence each type of waste i, $i = 1,...,I$ on every environmental element j, $j = 1,...,J$ is defined by measuring. Because of the nature of the problem, the assumption is introduced so that value of each type of waste i, $i = 1,...,I$ on every environmental element j, $j = 1,...,J$ is determined due to management team members assessment, their decision is made by consensus. In this problem management team members based their assessments on their experiences, literature data and the good practise results. The management team assessment is based on Saaty's [7] measuring scale [1-9], where the value 1, i.e. value 9, is represented to have small valuation, i.e. extreme valuation.

The value of every decision matrix element is counted as if mathematical product of relative importance of type waste *i*, *i* = 1,...,I on environmental elements *j*, *j* = 1,...,J, and their assessment values. Types of waste are ranked following all the environmental elements and is performed by using TOPSIS method [1]. Using normalisation procedure all matrix elements values of decision-making are copied into the set of real numbers [0-1] and they are comparable. In the literature there are many develop types of normalization [9]. In this paper the method of linear normalization is used.

4. SUGGESTED ALGORITHM

The ranking of influence of every identified waste type on environment was received by using modified TOPSIS method, which can be reduced through the next steps:

Step 1: We determine the assessment of relative importance of each management team member, $W_{i,j}^e$.

Step 2: We determine the aggregated relative importance assessment of management team members, $W_{i,j}$.

$$W_{i,j} = \sum_{e=1}^{E} W_e \cdot W_{i,j}^e$$

where W_e importance of management team member, *e*, *e = 1*,...,*E*.

Step 3: We assess the value of influence of every waste type *i*, *i* = 1,..,I on every environmental element *j*, *j* = 1,...,J $V_{i,j}$.

Step 4: We construct the matrix of determination D,

$$\mathrm{D} = \left[\mathrm{d_{ij}}\right]_{\mathrm{IxJ}}$$

where $d_{i,j} = W_{i,j} \cdot V_{i,j}$.

$d_{i,j}$ is weighted value *i*, *i* = 1,...,I on every environmental element *j*, *j* = 1,...,J.

Step 5: We normalize the values of determination matrix elements using linear normalization method, $\mathrm{r_{i,j}}$.

$$r_{i,j} = \frac{d_{i,j}}{\sum_{i=1}^{I} d_{i,j}}$$

Step 6: We determine positive ideal solution and negative ideal solution of influence every waste type *i*, *i* = 1,...,I on every environmental element *j*, *j* = 1,...,J.

$$\mathrm{r_j^+} = \max_{\mathrm{i=1,\dots,I}} \mathrm{r_{i,j}}$$

$$r_j^- = \min_{i=1,\dots,I} r_{i,j}$$

Step 7: We determine distance from r_j^+ and r_j^-.

$$n_i^+ = \sum_{j=1}^{J} |r_j^+ - r_{i,j}|$$

$$n_i^- = \sum_{j=1}^{J} |r_j^- - r_{i,j}|$$

Step 8: We calculate coefficient that is approximately alternative to the ideal solution, C_i.

$$C_i = \frac{r_i^-}{r_i^+ + r_i^-}$$

Step 9: We rank waste types due to net preference. The first place in ranking there is type of waste which affects environment the most. The same goes for reverse.

5. ILLUSTRATED EXAMPLE

In this section developed method will be showed, illustrated with an example where data, received from real production conditions, existed.

Based on experiences, literature data and good practice results, the management team members (quality manager, manager of environment and manager of production) bring out their assessment of influence value of each waste type *i*, *i* = 1,...,I on every environmental element *j*, *j* = 1,...,J. 13 types of waste have been identified by the management team.

Using developed algorithm (Step 1 to Step 2) aggregated assessment values of those who make decision have been calculated. Obtained values are showed in Table 2.

The value of each waste type depends on assessment of quantity. Based on literature data one can assume that the value of metal waste is 0,8, plastic waste 0,06, rubber 0,04, and other = 0,1 (Step 3 of developed algorithm).

Table 1. *The assessment of influence value of each waste type on every environmental (ground, air and water)*

	Waste types	Ground			Air			Water		
		Q	E	P	Q	E	P	Q	E	P
1.	Fuel (petrol)	3	2	1	4	3	1	2	1	1
2.	Diesel	4	4	2	6	5	3	3	3	1
3.	Organic waste	2	2	1	3	1	1	1	1	1
4.	Synthetic waste	3	4	4	4	4	3	2	3	3
5.	Polysynthetic waste	2	3	2	1	2	1	1	1	1
6.	Metal waste	2	3	4	1	1	3	2	4	5
7.	Plastic waste	3	4	4	2	3	3	1	1	2
8.	Rubber waste	4	5	3	1	2	1	3	4	3
9.	Cleaning substances (acetone, rags...)	3	2	2	5	4	4	4	3	3
10.	Metal spare parts	5	4	6	3	2	2	3	2	2
11.	Rubber spare parts	4	5	5	2	3	3	1	2	2
12.	Plastic spare parts	5	6	6	1	2	2	3	4	4
13.	Noise and vibration	3	1	2	2	1	1	5	4	3

Q – Quality manager
E – Manager of environment
P – Production manager

Using procedure which is presented in Step 4 of developed algorithm, weighted values of every identified type of waste are obtained. The matrix of determination is showed in Table 2.

Table 2. *The matrix of determination*

	Waste types	Ground	Air	Water
1.	Fuel (petrol)	0.202	0,277	0,127
2.	Diesel	0,35	0,477	0,25
3.	Organic waste	0,175	0,154	0,1
4.	Synthetic waste	0,373	0,375	0,273
5.	Polysynthetic waste	0,248	0,148	0,1
6.	Metal waste	2,384	1,2	2,968
7.	Plastic waste	0,2238	0,1638	0,075
8.	Rubber waste	0,1692	0,0592	0,1392
9.	Cleaning substances (acetone, rags...)	0,227	0,427	0,327
10.	Metal spare parts	3,816	1,816	1,816
11.	Rubber spare parts	0,1892	0,1092	0,0692
12.	Plastic spare parts	0,3438	0,1038	0,2238
13.	Noise and vibration	0,179	0,127	0,402

An example of calculating the first member of matrix of determination:

$$d_{1,1} = (3 \cdot 0{,}27 + 2 \cdot 0{,}48 \cdot 1 \cdot 0{,}25) \cdot 0{,}1 = 0{,}202$$

Using linear (Step 5 of developed algorithm) normalized values of matrix of determinations are received (see Table 3).

An example of calculating the first member of normalized determination matrix:

$$r_{1,1} = \frac{0{,}202}{0{,}202 + 0{,}35 + \cdots + 0{,}179}$$

$$r_{1,1} = \frac{0{,}202}{8{,}88} = 0{,}0228$$

Table 3. *Normalized determination matrix*

	Waste types	Ground	Air	Water
1.	Fuel (petrol)	0.0288	0,0509	0,0184
2.	Diesel	0,0394	0,0877	0,0363
3.	Organic waste	0,0198	0,0283	0,0146
4.	Synthetic waste	0,0421	0,0689	0,04
5.	Polysynthetic waste	0,0279	0,0272	0,0146
6.	Metal waste	0,2685	0,2207	0,432
7.	Plastic waste	0,0253	0,0301	0,0109
8.	Rubber waste	0,0109	0,0109	0,0203
9.	Cleaning substances (acetone, rags...)	0,0256	0,0785	0,0476
10.	Metal spare parts	0,4297	0,3341	0,2643
11.	Rubber spare parts	0,0214	0,0201	0,01
12.	Plastic spare parts	0,0387	0,0191	0,0327
13.	Noise and vibration	0,0202	0,0233	0,0584

In Step 6 of developed algorithm the positive ideal solution as well as negative ideal solution of every waste type influence i, i = 1,...,13 on every environmental element j, j = 1,...,3 is defined:

$$\mathrm{r}_{\mathrm{j}}^{+} = \max_{\mathrm{i}=1,\ldots,\mathrm{I}} \mathrm{r}_{\mathrm{i,j}}$$

$$r_j^{-} = \min_{i=1,\ldots,I} r_{i,j}$$

For the ground:

$$\mathrm{r}_1^{+} = 0{,}4297$$

$$r_1^{-} = 0{,}019$$

For the air:

$$\mathrm{r}_2^{+} = 0{,}3341$$

$$r_2^{-} = 0{,}0109$$

For the water:

$$\mathrm{r}_3^{+} = 0{,}432$$

$$r_3^{-} = 0{,}01$$

In Step 7 of developed algorithm the distance from r_j^{+} and r_j^{-} are defined. An example of distance determination for the first waste type (petrol) from r_j^{+} and r_j^{-}:

$$n_1^{+} = |0{,}0228 - 0{,}4297| + |0{,}0509 - 0{,}3341| + |0{,}0184 - 0{,}432| = 1{,}1037$$

$$n_1^{-} = |0{,}0228 - 0{,}0190| + |0{,}0509 - 0{,}0190| + |0{,}0184 - 0{,}01| = 0{,}0522$$

Coefficient of approximately ideal solution alternative, C_i is calculated in Step 8 of developed algorithm. Further on there is example of coefficient determination of approaching for the first waste type:

$$C_1 = \frac{0{,}0522}{0{,}0522 + 1{,}1037} = 0{,}0452$$

In Step 9, the ranking of identified type of waste is defined. Obtained ranking is showed in Table 4 and Table 5.

Table 4. *Ranking every type of waste influence on all the environmental elements*

	C_i	Ranking
1.	0,0452	7
2.	0,1068	3
3.	0,0197	11
4.	0,0961	5
5.	0,0258	9
6.	0,2376	2
7.	0,0228	10
8.	0,0071	13
9.	0,0967	4
10.	**0,8549**	**1**
11.	0,0100	12
12.	0,0438	8
13.	0,0536	6

Table 5. *The influence of every type of waste on environmental elements is ranked from top to the bottom.*

Rang	Waste types
1.	Metal spare parts
2.	Metal waste
3.	Diesel
4.	Cleaning substances (acetone, rags.)
5.	Synthetic waste
6.	Noise and vibration
7.	Fuel (petrol)
8.	Plastic spare parts
9.	Polysynthetic waste
10.	Plastic waste
11.	Organic waste
12.	Rubber spare parts
13.	Rubber waste

The first place takes the waste which affects environmental elements the most, and at the last there is waste which affects environmental elements at least.

6. CONCLUSION

On the basis of achieved result we could clearly see that the biggest effect on environment, with all the respect for all the environmental elements, simultaneously, metal spare parts have. The influence of all the other identified waste in regard to metal parts is significantly less than influence of metal parts. This result clearly shows that it is necessary for all appropriate measures need to be taken in order to lower the influence of metal parts. The influence of rubber waste is the least.

The paper has showed that on exact way it could be determined the influence of production process detoxification device on environment. The importance of every identified product is estimated by those who bring decisions. Since the production process is difficult and could be decomposed into a large number of subprocesses, an assumption is introduced so that management team members do not have equal importance. Within this assumption, the importance of every product on every environmental element is set as if group task decision-making. This could be classified as one of the main paper contribution. The value of each product is specified considering data from the record, respecting the amount of every type of waste. Other steps of TOPSIS method are the same as if convencional TOPSIS method.

Besides advantages paper has got some limits. The main limit refers to presentation of precise numbers by those who make decisions. The author opinion is that it is closer to human way of thinking if those who bring decisions should give their assessment with linguistic expressions. Modeling of linguistic expressions could be performed with soft computing methods, which present the subject of future researches.

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