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TAXONOMIC ASSESSMENT OF THE ENVIRONMENTAL PROBLEMS OF MOTOR TRANSPORT FACILITIES BASED ON THE EXAMPLE OF GENERATED WASTE

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Abstract

Environmentally conscious activities performed in, among other things, motor transport facilities are of considerable importance for the environmental protection. Unfortunately, the analysis of the situation confirms that environmental protection in this kind of facilities is put at the bottom of the agenda. The economic effect of the sale of services, backed up with the expenditure on marketing and oriented to the maximization of profits and not to the environmental protection still prevails. This paper discusses the choice of an environmental strategy for motor transport facilities using a taxonomic method. It provides the purpose for using this method to assess environmental issues and describes its determinants. Basic taxonomic equations an algorithm for the calculations are also presented. The taxonomic method is characterized on the example of harmfulness of generated waste. The paper presents the calculation results and their interpretation in respect of the choice of a suitable technology to be applied. The data pertaining to the nuisance from generated waste were collected from 15 companies offering motor transport services. In order to ensure credible results, we adopted the data for defined parameters collected during consultation meetings with the technical inspectors of the companies under study and with the employees assigned to specific jobs.

Keywords: *ecology, managing environmental problems, motor transport, technical facilities, taxonomic method*

1. Introduction

The development of motor transport and its consequence in the form of the growing number of vehicles used as well as easy access to such transport means cause considerable risks to this sector of economy. The main motor transport problems would include the environmental damage and the lack of technical facilities functioning appropriately in terms of inspections, repairs and diagnostic testing [8].

The solution of the most essential motor transport problems in Poland depends on quick investment and organizational decisions aimed at making the Polish transport system equal to the logistic systems used in EU countries.

The issues addressed in this article include a proposal of a logistic system strategy for motor transport facilities with respect to waste management by using a taxonomic method [1,6]. The taxonomic method enables comparison and choice of the most favourable solutions from among the considered technologies that are described by various parameters and units of measure. The ordering of technologies as factors according to defined criteria is closely related to systematics, on the basis of which the taxonomy functions.

2. Basic equations used in the taxonomic method and the algorithm for the calculations

The taxonomic method relates to theoretical principles, procedures and rules of classifying technical objects from an analytical perspective. The method allows for graphic presentation of an affinity between the operations based on the example of selected logistic management strategies that are considered in comparison with the distance within a multidimensional metric space. For the purpose of this paper, each coordinate means a specific parameter assigned to a strategy for managing environmental parameters. Dendrites for the selected parameter group are depicted in graphic form to enable search for the smallest average difference between these parameters. This method is used to search for a so called effective parameter group based on specific assumptions [2,3].

The parameters for a specific environmental management technology for motor transport facilities are physical and chemical quantities. In the taxonomic model, it is necessary to normalize parameters so that they take non-dimensional values. During the normalization it is important not to disrupt the correlations in particular technologies. Another important problem is the so called correspondence between parameters. It is important to make such limitations where all the covariance matrices of the technologies in question are identical.

The modelling algorithm for logistic processes in motor transport facilities can be presented in the following order [4,6]:

1) The vector for the management of environmental problems, comprised of n elements, has the following form:

$$x(t) = \left[\frac{x_1(t)}{x_n(t)} \right] \tag{1}$$

The above relationship is a time function but not in an evident way because each of the subsequent stages of the logistic process is a function of logistic indices for the management of environmental problems (eg $\mathbf{WN_1, \ldots, WN_n}$). So, this can be written as follows:

$$x(WN_1,\ldots,WN_n) = \left[\frac{x_1(WN_1,\ldots,WN_n)}{x_n(WN_1,\ldots,WN_n)} \right] \tag{2}$$

There are as many indices for the management of environmental problems as the system elements. They are chosen from among the system indices $\mathbf{WN_1}$ **-** $\mathbf{WN_n}$, defined separately for each element. Each of the $\mathbf{WN_i}$ indices can take various values within a definite time period (0, T) and can influence the management procedure xi as well as other procedures.

2) It is possible to digitize the time within the bracket of (0, T) by dividing the period into **K** short lengths of time, $\mathbf{\Delta t}$ long each:

$$\Delta t = \frac{T}{K} \tag{3}$$

Determining the value of the i-th index for the management of environmental problems with $\mathbf{k_i}$, the equation (2) can be at k-th time written as follows:

$$x(k_1,\ldots,k_n) = \left[\frac{x_1(k_1,\ldots,k_n)}{x_n(k_1,\ldots,k_n)} \right] \tag{4}$$

This equation presents the dependence of the vector for the logistics of the management of environmental problems from the digitized system indices.

3) Given the values of the system indices at times **k** (k = 1,..., K) it is possible to determine the value of the vector for the logistic system by using for this purpose a multidimensional discrete-time nonlinear model:

$$\left[\frac{x_1(k_1+1,...,k_n)}{x_n(k_1,...,k_n+1)}\right] = F\left\{\frac{x_1(k_1,...,k_n)}{x_n(k_1,...,k_n)}\right\} k_1,...,k_n = 1,...,K \quad (5)$$

where: F - vector function with independent variable being a vector for the logistic system.

4) The equation (5) can be written in a way that enables iterative determination of the vector for the logistic system.

$$\left[\frac{x_1(k_1+1,...,k_n)}{x_n(k_1,...,k_n+1)}\right] = F\left[\frac{f_1[x_1(k_1,...,k_n),...,x_n(k_1,...,k_n)]}{f_n[x_1(k_1,...,k_n),...,x_n(k_1,...,k_n)]}\right] \quad (6)$$

where: $f_1, ... ,f_n$ - functions describing the correlation between logistic procedures.

5) The logistic system vectors defined in the above way can be analysed by determining the spatial positions of the coordinates (the indices for the logistics of the management of environmental problems) in relation to the other, and thus determining the place in the entire sample. This in turn gives the ability to order and classify them. The indices for the management logistics are expressed in various units and cannot be added up directly. In this case one can use the method for relative mean differences expressed by the below formula:

$$R_{1,2} = \sum_{j=1}^{j=n} \left| \frac{WN_{1j} - WN_{2j}}{WN_{srj}} \right| \quad (7)$$

where:

$R_{1,2}$ - sum of the differences between the technologies,

WN_{1j} - value of the index for the logistics of the management of environmental problems of characteristic **j** of technology **1**,

WN_{2j} - value of the index for the logistics of the management of environmental problems of characteristic **j** of technology **2**,

WN_{srj} - mean value of the index for the logistics of the management of environmental problems of characteristic **j**.

6) The logistic system technologies can be ordered by dendrite method. The dendrite of the smallest differences between the indices for the logistics of the management of environmental problems, obtained as result of such ordering, graphically depicts the system clusters.

7) Given the sums of the differences between the indices for the management logistics, it is possible to construct a metric square matrix (by Czekanowski's method) that allows for verification of the dendrite ordering:

$$R = \begin{vmatrix} R_{11} & R_{12} & R_{13} & \cdots & R_{1m} \\ R_{21} & R_{22} & R_{23} & \cdots & R_{2m} \\ R_{31} & R_{32} & R_{33} & \cdots & R_{3m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ R_{n1} & R_{n2} & R_{n3} & \cdots & R_{nm} \end{vmatrix} \quad (8)$$

3. Taxonomic analysis of harmfulness of generated waste

As mentioned in the introduction to this paper, environmental problems related to the waste generated in motor transport facilities were assessed using the taxonomic method. The method allows for dendrite ordering that is better to reproduce the positions of the examined factors in the multidimensional parameter space, as opposed to all kinds of optimization method that allow for only linear ordering of selected indices [5].

For the taxonomic assessment of environmental threats resulting from the waste generated in motor transport facilities, their general harmfulness to the environment was chosen. The data pertaining to the nuisance from generated waste were collected from 15 companies, with the range of 0 or 1 (0 - least nuisance, 1- biggest nuisance) adopted. All the selected companies offer motor transport services. And all the motor transport companies under study are called "technologies" because, when making their documents and materials on generated waste available to us, some of them did not give their consent to their names and affiliations to be disclosed. The data adopted for the defined parameters were repeatedly consulted with the companies' technical inspectors and employees assigned to specific jobs to ensure that credible results are obtained [6,7].

The choice of the most favourable variant in respect of the adopted comparison criteria necessary to carry out an analysis by taxonomic method required three additional parameters correlated with environmental issues in those companies (i.e. model parameters) to be defined. Our in-depth analysis has allowed us to define the following: CO_2 emissions to the environment (WP1), total amount of waste material (WP2), and power demand in respect of environmentally friendly works (WP4). The fourth model parameter is the general harmfulness of generated waste (WP3). Table 1 includes the model parameters selected for calculations and their corresponding units of measure.

Tab. 1. Parameters for the environmental assessment of the technical facilities, chosen for the analysis

No	PARAMETER SYMBOL	PARAMETER TYPE	MEASUREMENT UNIT
1.	P1	Emission of carbon dioxide (CO_2) to atmosphere	[kg/rok]
2.	P2	Total quantity of material waste	[kg/rok]
3.	P3	General "harmfulness" of generated waste (in terms of toxicity)	[0-1]*
4.	P4	Energy demand with reference to pro-ecological projects	[kWh/m-c]

* 0 - lowest, 1 - highest

3.1. Study results

The results obtained by taxonomic method have been additionally verified in this paper by Czekanowski's matrices. In the case of similarity of the results it can be concluded that the procedure adopted for the calculations was correct. The order of the connected points and the values of the mean differences between those points matter greatly when drawing the conclusions. The closeness and the clustering of specified technologies show that the parameter concerned is similar, which allows selection of an optimal quantity.

The research results have been collated in tables and presented graphically in the form of dendrites and Czekanowski's matrices, including:

- table 2 - collation of the analysed parameters for all the companies under study,
- table 3 - parameter values determined by taxonomic method for the least troublesome waste with respect to environmental protection, in 5 of the companies under study,
- table 4 - mean differences between the technologies under study (according to table 3),
- table 5 - Czekanowski's diagonal matrix (verification: Fig. 1),
- table 6 - parameter values determined by taxonomic method for moderately troublesome waste with respect to environmental protection, in 5 of the companies under study,
- table 7 - mean differences between the technologies under study (according to table 6),
- table 8 - Czekanowski's diagonal matrix (verification: Fig. 2),
- table 9 - parameter values determined by taxonomic method for the most troublesome waste with respect to environmental protection, in 5 of the companies under study,
- table 10 - mean differences between the technologies under study (according to table 9),
- table 11 - Czekanowski's diagonal matrix (verification: Fig. 3),

- Fig. 1 - dendritic differentiation of the technologies according to harmfulness of the waste for the 5 lowest values,
- Fig. 2 - dendritic differentiation of the technologies according to harmfulness of the waste for the 5 medium values,
- Fig. 3 - dendritic differentiation of the technologies according to harmfulness of the waste for the 5 highest values.

Tab. 2. Analysed parameters for the 15 companies under research (including the model parameters)

Technology \ Parameters	P1	P2	P3	P4
1	929	58 518	0,35	800
2	1 328	63 372	0,72	900
3	1 679	55 846	0,27	950
4	1 000	31 982	0,26	600
5	2 647	113 516	0,13	975
6	1 221	48 288	0,49	740
7	3 017	106 424	0,31	250
8	1 921	84 961	0,87	1000
9	1 395	62 282	0,59	430
10	896	55 423	0,70	740
11	1 093	63 230	0,18	800
12	4 329	161 326	0,19	940
13	2 247	57 013	0,64	800
14	1 444	65 510	0,25	850
15	2 309	124 893	0,13	900
WP1	672	41 568	1	555
WP2	750	23 987	1	450
WP3	1 441	63 721	1	750
WP4	2 262	79 818	1	187,5

Tab. 3. List of parameters according to harmfulness of the waste for the 5 lowest values from among the companies under study

Technology \ Parameters	P1	P2	P3	P4
8	1 921	84 961	0,87	1000
2	1 328	63 372	0,72	900
10	896	55 423	0,70	740
13	2 247	57 013	0,64	800
9	1 395	62 282	0,59	430
WP1	672	41 568	1,00	555
WP2	750	23 987	1,00	450
WP3	1 441	63 721	1,00	750
WP4	2 262	79 818	1,00	188

Tab. 4. Mean differences between the technologies under study (according to table 3)

Technology	8	2	10	13	9	WP1	WP2	WP3	WP4
8		2146,98	2885,16	2694,37	2244,01	4220,54	5896,81	2060,95	1091,67
2	2146,98		836,40	931,81	542,67	2127,11	3803,37	357,72	1812,33

10	2885,16	836,40		615,15	1044,95	1342,40	3019,58	893,54	2626,04
13	2694,37	931,81	615,15		900,94	1623,59	3238,84	802,90	2539,55
9	2244,01	542,67	1044,95	900,94		2121,03	3682,79	550,84	1883,30
WP1	4220,54	2127,11	1342,40	1623,59	2121,03		1689,32	2163,82	3809,71
WP2	5896,81	3803,37	3019,58	3238,84	3682,79	1689,32		3837,11	5411,25
WP3	2060,95	357,72	893,54	802,90	550,84	2163,82	3837,11		2001,91
WP4	1091,67	1812,33	2626,04	2539,55	1883,30	3809,71	5411,25	2001,91	

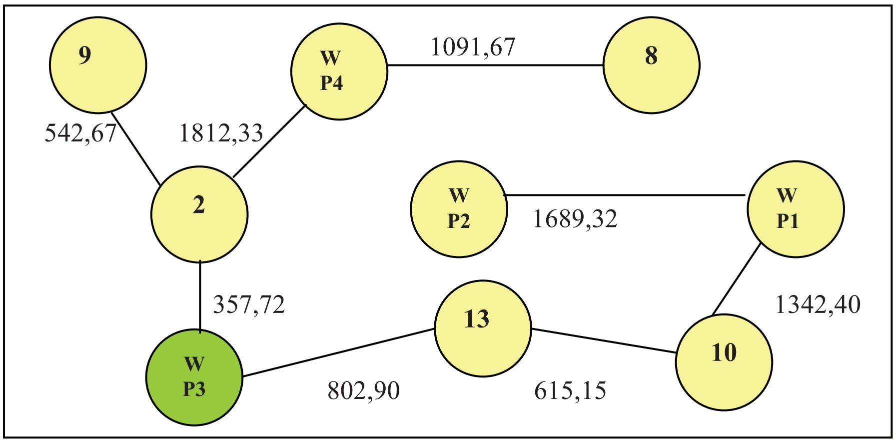
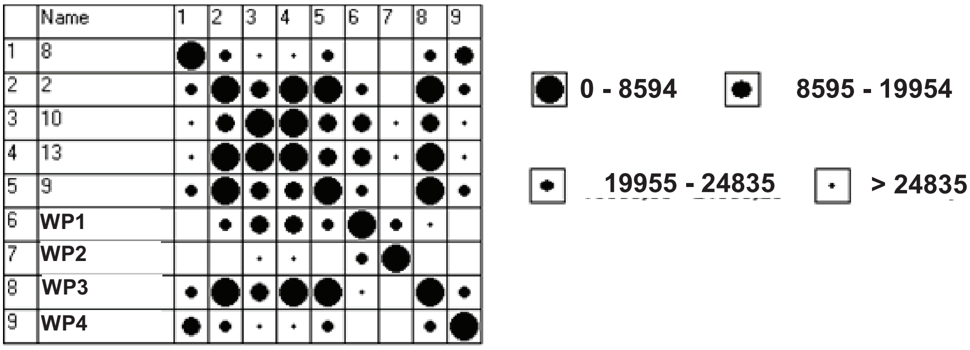


Fig. 1. Dendritic differentiation of the technologies according to harmfulness of the waste for the 5 lowest values

Tab. 5. Czekanowski's diagonal matrix (dendrite verification according to Fig. 1)



Tab. 6. Parameters according to harmfulness of the waste for the 5 medium values from among the companies under study

Parameters / Technology	P1	P2	P3	P4
6	1 221	48 288	0,49	740
1	929	58 518	0,35	800
7	3 017	106 424	0,31	250
3	1 679	55 846	0,27	950
4	1 000	31 982	0,26	600
WP1	672	41 568	1,00	555
WP2	750	23 987	1,00	450
WP3	1 441	63 721	1,00	750
WP4	2 262	79 818	1,00	188

Tab. 7. Mean differences between the technologies under study (according to table 6)

Technology	6	1	7	3	4	WP1	WP2	WP3	WP4
6		1319,63	5704,15	1195,88	1572,25	970,27	2352,95	1677,59	3221,37
1	1319,63		4774,70	819,90	2548,44	1707,93	3320,58	1080,33	2371,91
7	5704,15	4774,70		5034,81	7215,07	6315,27	7981,52	4214,46	2577,86
3	1195,88	819,90	5034,81		2358,06	1568,22	3105,89	989,99	2590,46
4	1572,25	2548,44	7215,07	2358,06		1009,37	783,42	3058,33	4645,56
WP1	970,27	1707,93	6315,27	1568,22	1009,37		1689,32	2163,82	3809,71
WP2	2352,95	3320,58	7981,52	3105,89	783,42	1689,32		3837,11	5411,25
WP3	1677,59	1080,33	4214,46	989,99	3058,33	2163,82	3837,11		2001,91
WP4	3221,37	2371,91	2577,86	2590,46	4645,56	3809,71	5411,25	2001,91	

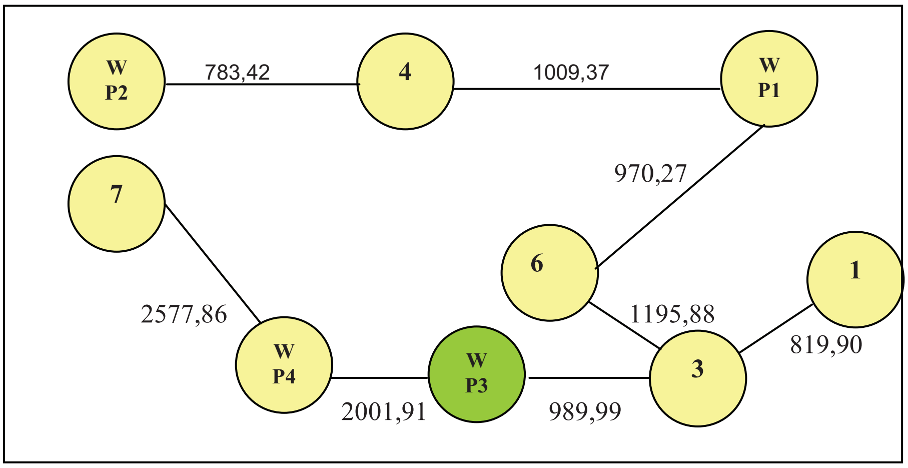
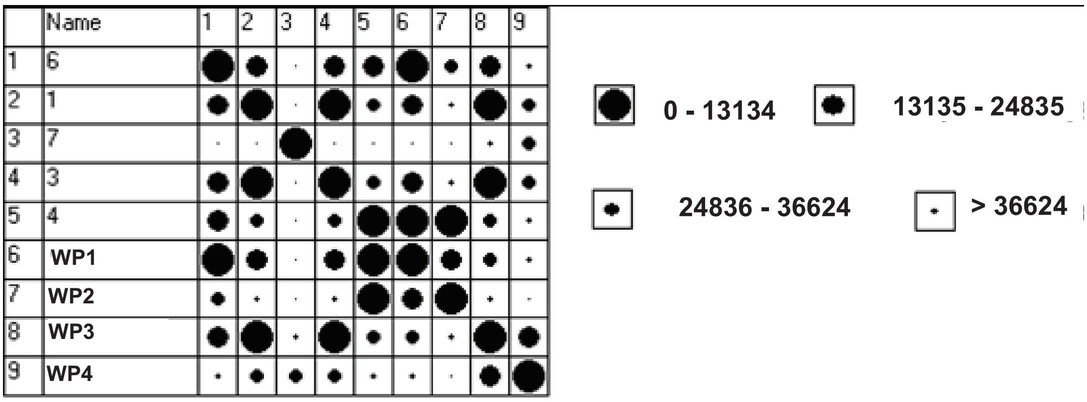


Fig. 2. Dendritic differentiation of technologies according to harmfulness of the waste for the 5 medium values

Tab. 8. Czekanowski's diagonal matrix (verification: Fig. 2)



Tab. 9. Parameters according to harmfulness of the waste for the 5 highest values

Technology \ Parameters	P2	P13	P14	P21
14	1 444	65 510	0,25	850
12	4 329	161 326	0,19	940
11	1 093	63 230	0,18	800
15	2 309	124 893	0,13	900
5	2 647	113 516	0,13	975
WP1	672	41 568	1,00	555
WP2	750	23 987	1,00	450
WP3	1 441	63 721	1,00	750
WP4	2 262	79 818	1,00	188

Tab. 10. Mean differences between the technologies under study (according to table 9)

Technology	14	12	11	15	5	WP1	WP12	WP3	WP4
14		9277,03	1264,60	5865,67	5021,38	2335,36	4011,45	745,66	1824,96
12	9277,03		9510,66	3703,76	4645,04	11609,48	13285,65	9450,61	7901,15
11	1264,60	9510,66		5941,20	4989,51	2251,43	3776,22	912,86	1757,25
15	5865,67	3703,76	5941,20		2029,78	8037,54	9714,72	5919,93	4383,47
5	5021,38	4645,04	4989,51	2029,78		7041,35	8650,23	5360,95	3710,97
WP1	2335,36	11609,48	2251,43	8037,54	7041,35		1689,32	2163,82	3809,71
WP2	4011,45	13285,65	3776,22	9714,72	8650,23	1689,32		3837,11	5411,25
WP3	745,66	9450,61	912,86	5919,93	5360,95	2163,82	3837,11		2001,91
WP4	1824,96	7901,15	1757,25	4383,47	3710,97	3809,71	5411,25	2001,91	

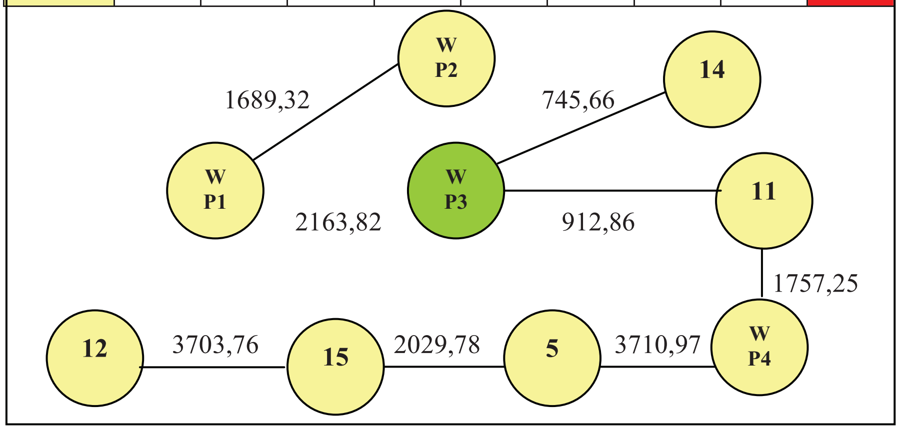
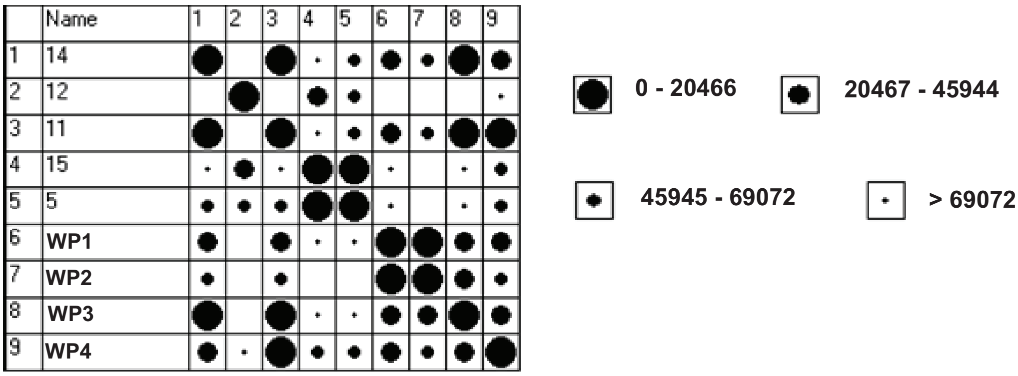


Fig. 3. Dendritic differentiation of technologies according to harmfulness of the waste for the 5 highest values

Tab. 11. Czekanowski's diagonal matrix (verification: Fig. 3)



4. Conclusions

Ordering of environmentally conscious technologies by taxonomic method in a motor transport facility is an effective way of finding an appropriate solution. The taxonomic method can also be used to effectively choose a logistic system for environmental threats occurring in a motor transport facility. Czekanowski's matrices can be employed to additionally verify the differentiation results for environmentally conscious technologies and logistic systems.

The evaluation of the results treated in this paper allows for their interpretation with respect to the usefulness of the technologies in question. The list covering the harmfulness of the waste for the group of 5 companies characterized by the slightest impact on the environment shows that the company behind the number 2 is in the most favourable situation in this respect. Moreover, taxonomic differentiation allows us to state that technology no. 2 is also in a favourable situation with respect to power consumption (the model technology WP4 is also close to technology no. 8).

The same dendrite also reveals that the desirable technology can be company no. 13 which is close to WP3 in the taxonomic space.

In the group of companies ordered according to the mean harmfulness of the waste, the technology behind no. 3 has the lowest value which means that it is in the most favourable situation in terms of its impact on the environment. Technology no. 6 is close to the model technology WP1 which is not insignificant on account of CO_2 emissions (the greenhouse effect). This is revealed by dendritic differentiation of the technologies and confirmed by Czekanowski's diagram.

In the group of 5 companies that are the most troublesome to the environment in terms of harmfulness of the waste they generate the best technologies are numbered 11 and 14. Technology no. 14 that is closest to the model value WP3 in the taxonomic space is characterized by the lowest value of parameter P3 in this group of companies. Dendrite ordering is verified by Czekanowski's diagonal matrix which shows similar results.

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