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THE TAXONOMIC ANALYSIS OF ECOLOGICAL THREATS CAUSED BY A TECHNICAL INFRASTRUCTURE OF MOTOR TRANSPORT BASED ON THE TOTAL QUANTITY OF MATERIAL WASTE

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Abstract

The article presents the matters connected with modelling an ecological strategy using a taxonomic method for a technical infrastructure of motor transport. The ecological problems are exceptionally crucial for this sphere of service activities of transport means. The article shows the essential facilities of a technical infrastructure required for proper service operation with related ecological threats. It also presents the justification for using a taxonomic method to evaluate ecological issues. Based on the total quantity of material waste, the article presents the method, calculation results and their interpretation concerning the choice of an appropriate technology for application.

Keywords: *ecology, motor transport, technical support equipment of transport, taxonomic method*

1. Introduction

Motor transport plays a significant role in functioning of a market, not only a local, regional or domestic one, but it also has a global dimension [9]. Its development is accompanied by specific conditionings and their consequences. The development of a transport infrastructure, increasing number of roads and technical infrastructure facilities in addition to greater and greater motor traffic intensity, cause the necessity to put serious interest in safety of road traffic, reliability of devices and systems as well as protection of natural environment.

The ecological issues are important for the automotive branch, ranging from a vehicle design phase up to a recycling one [3,5]. The dynamic development and the expansion of motorization started to penetrate the environment without limits and without taking negative consequences into account. The direct result is still air, soil, surface and subterranean waters pollution, noise emission, the intensification of the greenhouse effect and the increase in quantity of waste products generated during operation and recycling of motor vehicles. An improperly organized and functioning technical infrastructure may also pose a serious threat to surrounding environment. This article addresses these issues and recommends an appropriate strategy for a logistic system for a technical infrastructure in the aspect of ecological problems.

2. Ecological threats caused by a technical infrastructure of motor transport

A technical infrastructure equipped with installations of adequate quality and special tools is of basic importance for the development of motor transport, because it enables proper operation of vehicles. An unsuitably organized and functioning technical infrastructure causes premature wear or even devastation of vehicles, reduction of transport capabilities, and above all, inevitable losses in individual sectors of a national economy. A properly prepared technical infrastructure keeps motor vehicles in adequate condition, which in turn, enables them to be ready to operate immediately [2,11].

A technical infrastructure involves properly prepared and equipped facilities, which are designated to maintain and supply vehicles, their sale or rent, perform technical services and warranty or periodic inspections, comprehensive or selective diagnostics of functional blocks, perform routine or accident repairs, collect retired vehicles for recycling etc. [4,8].

The most crucial ecological problems concerning a technical infrastructure of transport are [15]:

- air pollution with exhaust fumes in places for servicing or repairing vehicles (operating engines),
- noise emission in aforementioned places (operating engines),
- management and possible recycling of operating fluids (motor oil, gear oils, brake and power steering oils, brake fluid, cooling fluids, AC fluids etc.),
- management of used and replaced units, subsets and elements (steel elements, non-iron metals, polymers, rubber elements etc.) during inspections or repairs,
- protection of environment against harmful influence of disposal sites for used vehicles designated for recycling.

3. The estimation of the total quantity of waste material in a technical infrastructure of motor transport

The flexible and automatic processes that are employed currently in facilities of a technical infrastructure of motor transport are characterized by great variety and innovation. The introduction of new strategies makes it possible to quickly reduce power and material consumption of transport means. A numerical taxonomy method can be used to help achieve optimal efficiency and accuracy [10]. This solution is close to conditions which concern transport means, that is why such an approach differs from other known optimization methods.

The reason for using the taxonomic method to analyse ecological problems occurring in a technical infrastructure was imposed because of parameters that together with descriptions of technological issues, intrinsically have different physical values and different measurement units. The structure of taxonomic models makes it possible to arrange researched technologies in a linear way, so it mirrors their location better within a multidimensional space of parameters. The taxonomic method is employed in natural science to good effect. In technical applications, projects which grasp comprehensively the issues of using those methods appear very rarely. Using this method to develop a logistic system with an ecological aspect in mind, establishes a new quality for technical applications.

In this article, the total quantity of material waste generated during performance of services has been chosen to be analysed with the taxonomic method. 15 companies contributed to the data concerning the quantity of material waste, with the assumption of the quantity of waste in a year, i.e. [kg/year] as a measurement unit. Selected companies belong to different ownership and organizational structures; among them there are economic entities offering wide range of services, as well as technical infrastructures of car showrooms, farm organizations, municipal and intercity transport, transport and spedition companies etc. Some of the analysed companies while giving access to documentation and materials with the range of logistic activities, have not agreed to reveal their names and affiliations; that is why they are named "technologies" in the article.

Since the taxonomic method requires the choice of the most beneficial variant with regard to accepted criteria, three additional parameters (so called exemplary) have been selected, which concern:

- CO_2 emission - WP1,
- overall "quality" of generated waste with regard to toxicity - WP3,
- energy demand with reference to pro-ecological projects - WP4.

The total quantity of material waste generated while providing services remains the fourth exemplary parameter - WP2. In table 1, there are exemplary parameters and their corresponding measurement units, which have been selected for calculations.

Tab. 1. The parameters for pro-ecological assessment of a technical infrastructure of transport selected for analysis

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

* 0 - lowest, 1 - highest

The acquisition of the information regarding the selected parameters has run into serious difficulties in some companies. The required data has not always been found in available documentation, for instance due to briefness, treatment of waste as a total without selection with regard to a type, the lack of competence of employees responsible for this issue etc. That is why, the information concerning the individual parameters is the result of the additional analyses of statistical data relative to the quantity of performed inspections, repairs, diagnostic assessments and other services within specified time. Accepted data for the selected parameters have been consulted repeatedly with technical supervision of the analysed companies, or even directly with the employees engaged in specific types of work, just to gain the most adequate and reliable results.

3.1. The interpretation of the study results

The description of the methodology for performing study, the basic taxonomic method equations and the algorithm for performing calculations concerning the ecological problems of technical infrastructure of transport have been included in their own elaborations, in treatises among others [12,13,14]. That is why the description of these issues has been omitted. The detailed method for determining the 4 exemplary parameters has been presented in the thesis [13].

The results of the study using the taxonomic method (dendrites) have been verified additionally by the Czekanowski's matrix [6,7]. In the event of the convergence of the results, it can be concluded that the accepted procedure for calculations is correct and it authorizes the unequivocal interpretation during formulation of conclusions.

During the analysis of the results and drawing conclusions, the basic role is played by the sequence of connected points and the values of average differences between these points. Proximity and grouping of the particular technologies which indicate the similarity of the examined parameter enable the choice of the optimal value.

The study results have been presented in a tabular and a graphical way as dendrites and the Czekanowski's matrix, namely:

- tab. 2 - a list of analysed parameters for each surveyed company (with exemplary parameters),
- tab. 3 - values of parameters determined according to the taxonomic method for the lowest quantity of waste in 5 companies among the surveyed,
- tab. 4 - average differences between surveyed technologies (according to table 3),
- tab. 5 - the diagonal matrix of Czekanowski (dendrite verification according to fig. 1),
- tab. 6 - values of parameters determined according to the taxonomic method for the average

quantity of waste in 5 companies among the surveyed,

- tab. 7 - average differences between surveyed technologies (according to table 6),
- tab. 8 - the diagonal matrix of Czekanowski (dendrite verification according to fig. 2),
- tab. 9 - values of parameters determined according to the taxonomic method for the highest quantity of waste in 5 companies among the surveyed,
- tab. 10 - average differences between surveyed technologies (according to table 9),
- tab. 11 - the diagonal matrix of Czekanowski (dendrite verification according to fig. 3),
- tab. 12 - average differences between the analysed technologies for each of the surveyed companies (according to table 2),
- tab. 13 - the diagonal matrix of Czekanowski for each examined technologies (dendrite verification according to fig. 4),
- fig. 1 - a dendrite for a differentiation of a technology according to the sum of waste for the 5 lowest values,
- fig. 2 - a dendrite for a differentiation of a technology according to the sum of waste for the 5 average values,
- fig. 3 - a dendrite for a differentiation of a technology according to the sum of waste for the 5 highest values,
- fig. 4 - a total dendrite for a differentiation of a technology according to the sum of waste for all 15 surveyed companies.

Tab. 2. A list of analysed parameters for each surveyed company (with exemplary parameters)

Parameters / Technology	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. Values of parameters for the lowest quantity of waste in 5 companies among the surveyed

Technology \ Parameters	P1	P2	P3	P4
4	1 000	31 982	0,26	600
6	1 221	48 288	0,49	740
10	896	55 423	0,70	740
3	1 679	55 846	0,27	950
13	2 247	57 013	0,64	800
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. Average differences between surveyed technologies (according to tab. 3)

Technology	4	6	10	3	13	WP1	WP2	W3	WP4
4		1572,25	2252,50	2358,06	2502,58	1009,37	783,42	3058,33	4645,56
6	1572,25		1145,92	1195,88	1180,95	970,27	2352,95	1677,59	3221,37
10	2252,50	1145,92		534,46	615,15	1342,40	3019,58	893,54	2626,04
3	2358,06	1195,88	534,46		632,57	1568,22	3105,89	989,99	2590,46
13	2502,58	1180,95	615,15	632,57		1623,59	3238,84	802,90	2539,55
WP1	1009,37	970,27	1342,40	1568,22	1623,59		1689,32	2163,82	3809,71
WP2	783,42	2352,95	3019,58	3105,89	3238,84	1689,32		3837,11	5411,25
WP3	3058,33	1677,59	893,54	989,99	802,90	2163,82	3837,11		2001,91
WP4	4645,56	3221,37	2626,04	2590,46	2539,55	3809,71	5411,25	2001,91	

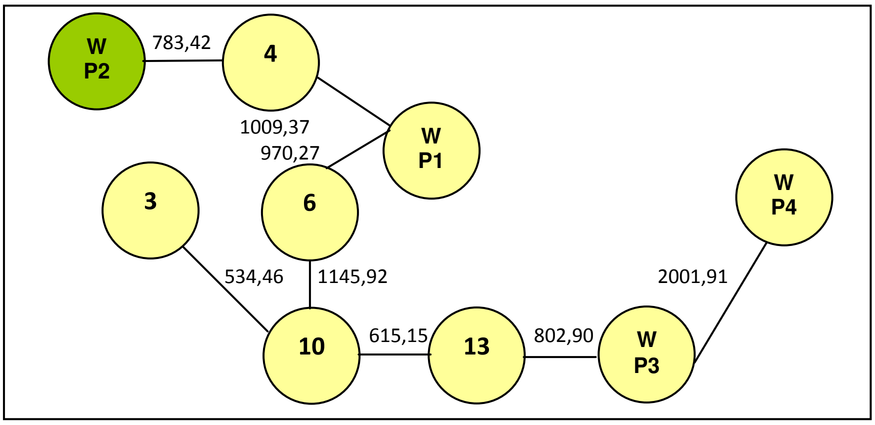
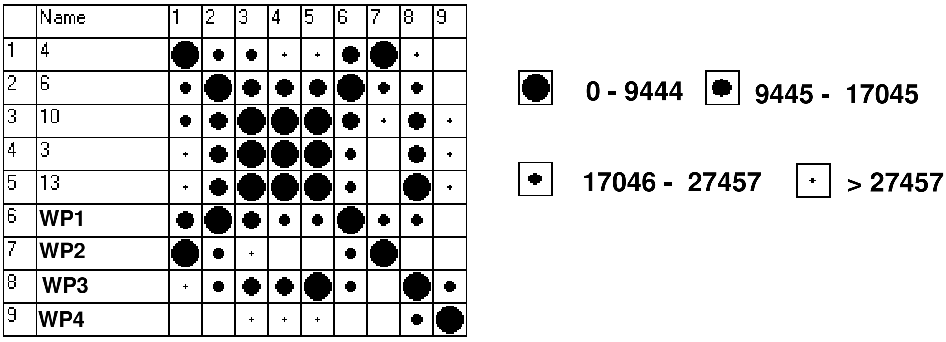


Fig. 1. A dendrite for a differentiation of a technology according to the sum of waste for the 5 lowest values

Tab. 5. The diagonal matrix of Czekanowski (dendrite verification according to fig. 1)



Tab. 6. Values of parameters for the average quantity of waste in 5 companies among the surveyed

Technology \ Parameters	P1	P2	P3	P4
1	929	58 518	0,35	800
9	1 395	62 282	0,59	430
11	1 093	63 230	0,18	800
2	1 328	63 372	0,72	900
14	1 444	65 510	0,25	850
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. Average differences between surveyed technologies (according to tab. 6)

Technology	1	9	11	2	14	WP1	WP2	WP3	WP4
1		1226,35	1567,27	886,19	966,97	1707,93	3320,58	1080,33	2371,91
9	1226,35		752,88	542,67	951,12	2121,03	3682,79	550,84	1883,30
11	1567,27	752,88		851,67	1264,60	2251,43	3776,22	912,86	1757,25
2	886,19	542,67	851,67		479,62	2127,11	3803,37	357,72	1812,33
14	966,97	951,12	1264,60	479,62		2335,36	4011,45	745,66	1824,96
WP1	1707,93	2121,03	2251,43	2127,11	2335,36		1689,32	2163,82	3809,71
WP2	3320,58	3682,79	3776,22	3803,37	4011,45	1689,32		3837,11	5411,25
WP3	1080,33	550,84	912,86	357,72	745,66	2163,82	3837,11		2001,91
WP4	2371,91	1883,30	1757,25	1812,33	1824,96	3809,71	5411,25	2001,91	

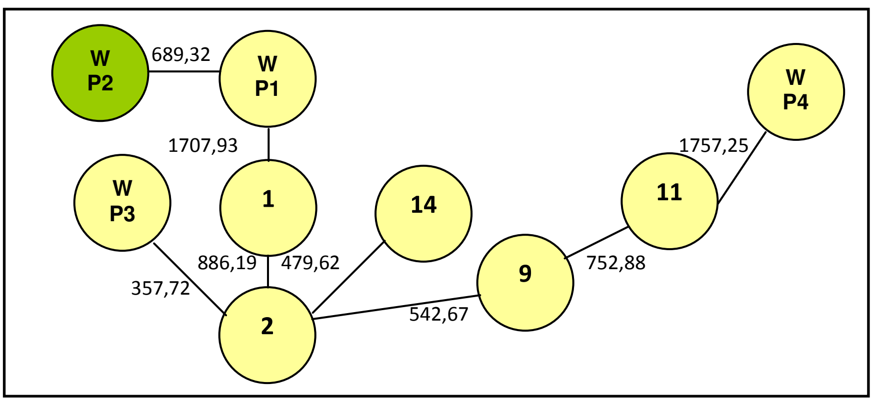
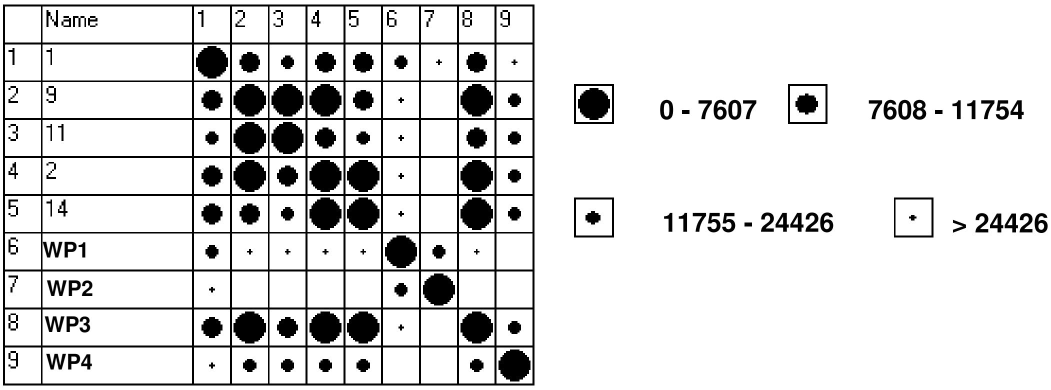


Fig. 2. A dendrite for a differentiation of a technology according to the sum of waste for the 5 average values

Tab. 8. The diagonal matrix of Czekanowski (dendrite verification according to fig. 2)



Tab. 9. Values of parameters for the highest quantity of waste in 5 companies among the surveyed

Technology \ Parameters	P1	P2	P3	P4
8	1 921	84 961	0,87	1000
7	3 017	106 424	0,31	250
5	2 647	113 516	0,13	975
15	2 309	124 893	0,13	900
12	4 329	161 326	0,19	940
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. Average differences between surveyed technologies (according to tab. 9)

Technology	8	7	5	15	12	*WP1*	WP2	WP3	WP4
8		2669,30	3767,05	4225,07	7466,31	4220,54	5896,81	2060,95	1091,67
7	2669,30		2158,48	2009,37	5340,02	6315,27	7981,52	4214,46	2577,86
5	3767,05	2158,48		2029,78	4645,04	7041,35	8650,23	5360,95	3710,97
15	4225,07	2009,37	2029,78		3703,76	8037,54	9714,72	5919,93	4383,47
12	7466,31	5340,02	4645,04	3703,76		11609,48	13285,65	9450,61	7901,15
WP1	4220,54	6315,27	7041,35	8037,54	11609,48		1689,32	2163,82	3809,71
WP2	5896,81	7981,52	8650,23	9714,72	13285,65	1689,32		3837,11	5411,25
WP3	2060,95	4214,46	5360,95	5919,93	9450,61	2163,82	3837,11		2001,91
WP4	1091,67	2577,86	3710,97	4383,47	7901,15	3809,71	5411,25	2001,91	

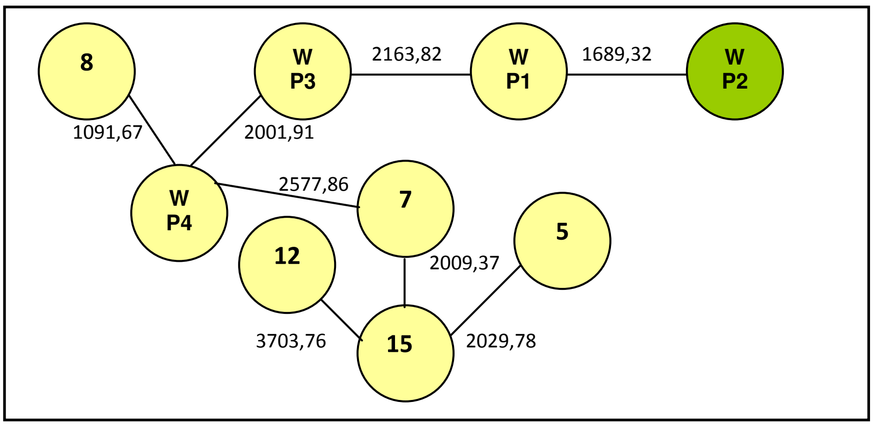
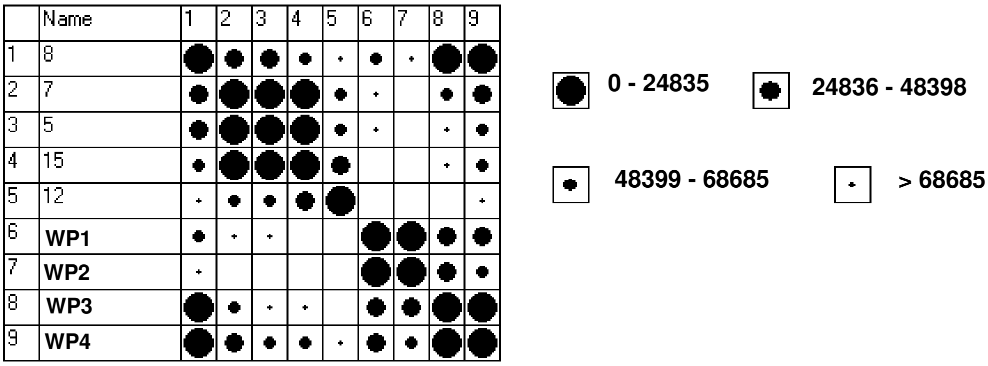


Fig. 3. A dendrite for a differentiation of a technology according to the sum of waste for the 5 highest values

Tab. 11. The diagonal matrix of Czekanowski (dendrite verification according to fig. 3)



Tab. 12. Average differences between the analysed technologies for each of the surveyed companies (according to tab. 2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	WP1	WP2	WP3	WP4
1		886,19	819,90	2548,44	5598,28	1319,63	4774,70	2831,19	1226,35	726,35	1567,27	9966,61	839,54	966,97	6397,88	1707,93	3320,58	1080,33	2371,91
2	886,19		911,61	3023,67	5181,97	1554,10	4277,94	2146,98	542,67	836,40	851,67	9483,09	931,81	479,62	5911,77	2127,11	3803,37	357,72	1812,33
3	819,90	911,61		2358,06	5562,80	1195,88	5034,81	2813,09	1101,31	534,46	1315,79	10182,73	632,57	1076,63	6617,01	1568,22	3105,89	989,99	2590,46
4	2548,44	3023,67	2358,06		7866,92	1572,25	7215,07	5116,20	2918,23	2252,50	3085,24	12506,66	2502,58	3232,55	8931,42	1009,37	783,42	3058,33	4645,56
5	5598,28	5181,97	5562,80	7866,92		6405,15	2158,48	3767,05	5332,56	5845,68	4989,51	4645,04	5712,36	5021,38	2029,78	7041,35	8650,23	5360,95	3710,97
6	1319,63	1554,10	1195,88	1572,25	6405,15		5704,15	3544,41	1812,08	1145,92	1993,45	10934,79	1180,95	1804,60	7362,17	970,27	2352,95	1677,59	3221,37
7	4774,70	4277,94	5034,81	7215,07	2158,48	5704,15		2669,30	4301,99	5079,70	4253,62	5340,02	4868,65	4302,35	2009,37	6315,27	7981,52	4214,46	2577,86
8	2831,19	2146,98	2813,09	5116,20	3767,05	3544,41	2669,30		2244,01	2885,16	2120,69	7466,31	2694,37	2204,77	4225,07	4220,54	5896,81	2060,95	1091,67
9	1226,35	542,67	1101,31	2918,23	5332,56	1812,08	4301,99	2244,01		1044,95	752,88	9606,77	900,94	951,12	6037,82	2121,03	3682,79	550,84	1883,30
10	726,35	836,40	534,46	2252,50	5845,68	1145,92	5079,70	2885,16	1044,95		1262,10	10271,86	615,15	1052,61	6695,79	1342,40	3019,58	893,54	2626,04
11	1567,27	851,67	1315,79	3085,24	4989,51	1993,45	4253,62	2120,69	752,88	1262,10		9510,66	1221,75	1264,61	5941,21	2251,43	3776,18	912,82	1757,21
12	9966,61	9483,09	10182,73	12506,66	4645,04	10934,79	5340,02	7466,31	9606,77	10271,86	9510,66		10048,75	9277,03	3703,76	11609,48	13285,65	9450,61	7901,15
13	839,54	931,81	632,57	2502,58	5712,36	1180,95	4868,65	2694,37	900,94	615,15	1221,75	10048,75		1207,25	6476,00	1623,59	3238,84	802,90	2539,55
14	966,97	479,62	1076,63	3232,55	5021,38	1804,60	4302,35	2204,77	951,12	1052,61	1264,61	9277,03	1207,25		5865,67	2335,36	4011,45	745,66	1824,96
15	6397,88	5911,77	6617,01	8931,42	2029,78	7362,17	2009,37	4225,07	6037,82	6695,79	5941,21	3703,76	6476,00	5865,67		8037,54	9714,72	5919,93	4383,47
WP1	1707,93	2127,11	1568,22	1009,37	7041,35	970,27	6315,27	4220,54	2121,03	1342,40	2251,43	11609,48	1623,59	2335,36	8037,54		1689,32	2163,82	3809,71
WP2	3320,58	3803,37	3105,89	783,42	8650,23	2352,95	7981,52	5896,81	3682,79	3019,58	3776,18	13285,65	3238,84	4011,45	9714,72	1689,32		3837,11	5411,25
WP3	1080,33	357,72	989,99	3058,33	5360,95	1677,59	4214,46	2060,95	550,84	893,54	912,82	9450,61	802,90	745,66	5919,93	2163,82	3837,11		2001,91
WP4	2371,91	1812,33	2590,46	4645,56	3710,97	3221,37	2577,86	1091,67	1883,30	2626,04	1757,21	7901,15	2539,55	1824,96	4383,47	3809,71	5411,25	2001,91	

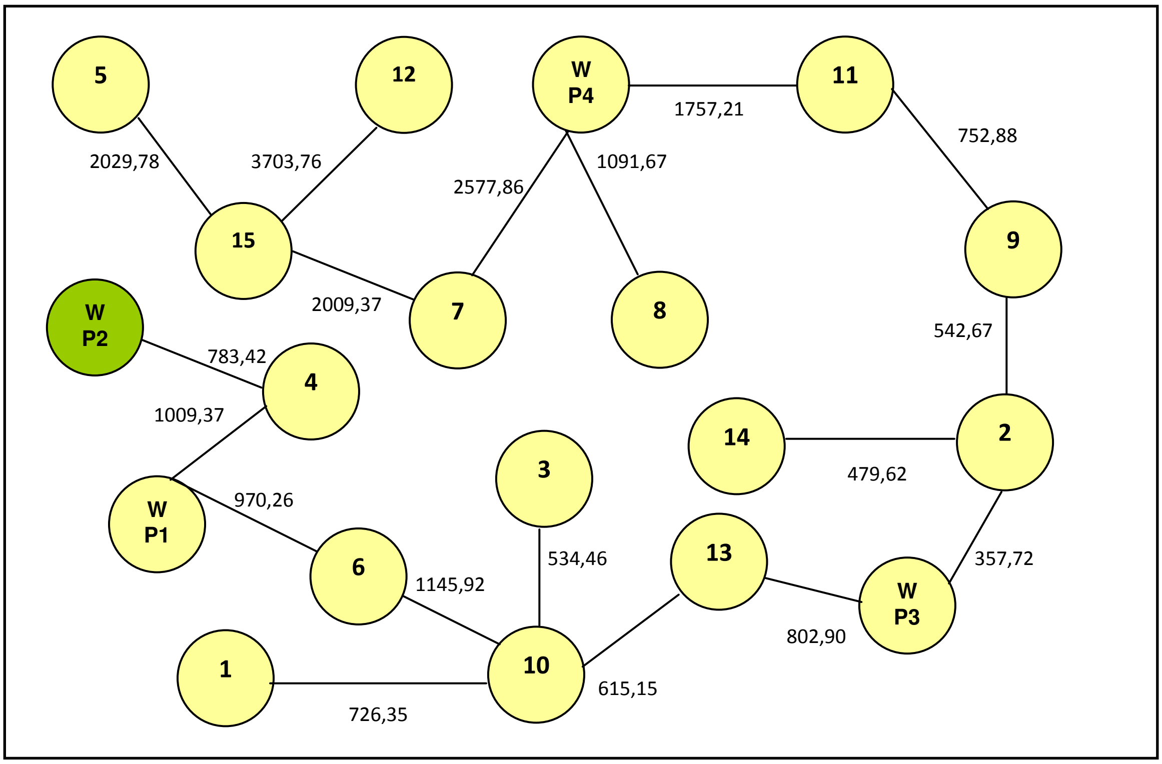
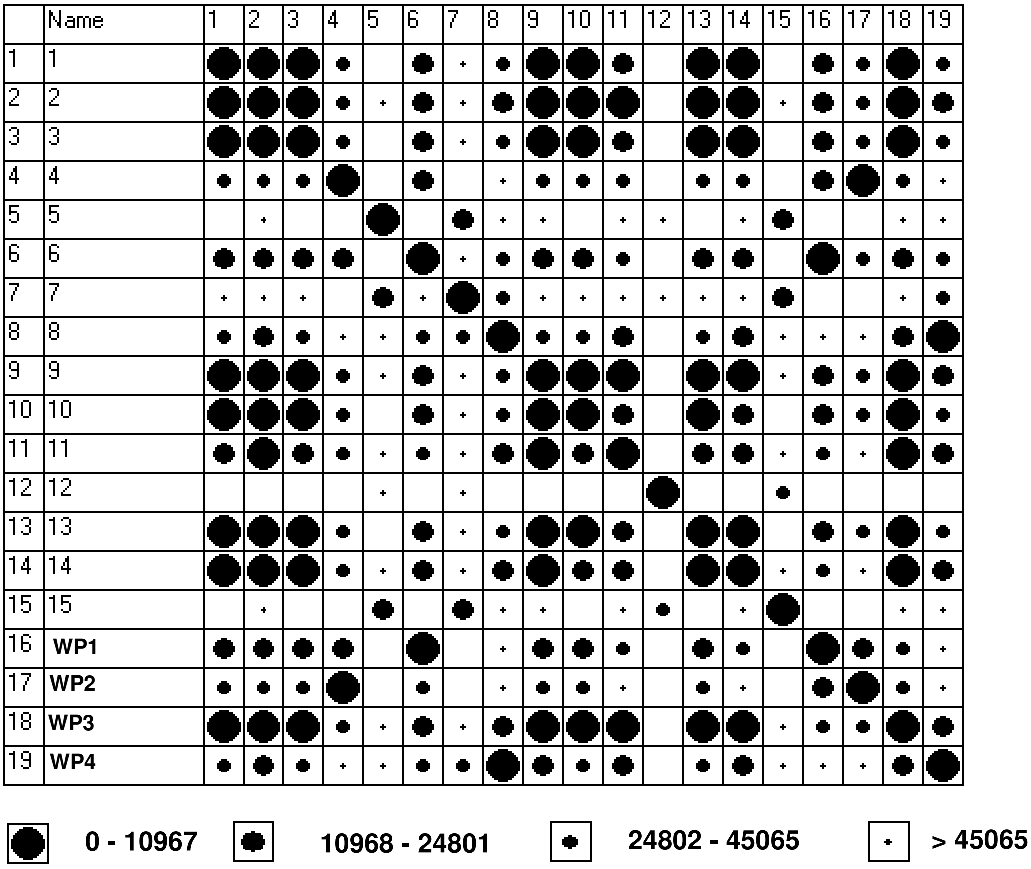


Fig. 4. A total dendrite for a differentiation of a technology according to the sum of waste for all 15 surveyed companies

Tab. 13. The diagonal matrix of Czekanowski for each examined technologies (dendrite verification according to fig. 4)



The analysis of the compiled results enables their interpretation in relation to the usefulness of the examined technologies:

- among the technologies with the lowest quantity of waste, the No. 4 technology is the most beneficial, because it appears a short taxonomic distance away from the WP2 exemplary technology; the No. 4 technology is also preferred due to the proximity to the WP1 exemplary technology and should be recommended for using in other companies,
- the analysis of the technology with the average values of the sum of waste, points at the No. 1 technology as the most beneficial, which places itself relatively close to the WP1 exemplary technology,
- within the group of the technologies with the highest quantity of gathered waste, the No. 8 technology is the most beneficial, showing the lowest values with reference to the WP4 exemplary technology.

Performing the analysis of the diagonal matrix of Czekanowski, in each of the three examined cases regarding the quantity of gathered waste, we confirm the results obtained by the taxonomic method. The diagonal matrix, which also includes all of the examined technologies, verifies the total dendrite positively.

4. Conclusions

The dynamic development of motor transport is connected with the necessity to reduce its negative impact on natural environment [1,15]. The facilities of a technical infrastructure are major participants in degradation of natural environment, due to diagnostic, routine and periodic inspections, repairs and other services concerning vehicles (e.g. car washes, paint shops etc.), which are performed there.

Using the taxonomic method allows for a dendritic arrangement, which mirrors the location of the examined factors within a multidimensional space of parameters, as opposed to any type of optimization method, which only allows for a linear arrangement of the selected problem indicators, occurring in a technical infrastructure of transport. The realisation of the subject matter presented in this article makes it possible to formulate the following conclusions of a general character:

- arranging pro-ecological technologies in a technical infrastructure of motor transport, using the taxonomic method is an effective way to find the point determined by the defined criteria within the space of the selected parameters,
- there is a possibility to verify the results of differentiation of pro-ecological technologies using the method of dendrite arrangement with the help of the diagonal matrix of Czekanowski,
- the dendritic arrangement with the taxonomic method and the matrix one with Czekanowski's method with reference to pro-ecological technologies in a technical infrastructure of motor transport give concurrent results,
- the taxonomic method can be used to choose a logistic system effectively with regard to the ecological problems of a technical infrastructure.

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