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VARIANT ASSESSMENT OF EXPLOITATION POLICY OF SELECTED COMPANIES MANAGING TECHNICAL NETWORK SYSTEMS

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Abstract:
The article presents the practical conditions of the implementation of the taxonomic method for assessing the exploitation policy, developed by the author and described in the article entitled Methodology of variant assessment of exploitation policy using numerical taxonomy tools (Management Systems in Production Engineering no 2(18)/2015) [19]. In the first part of the article, the elaborated (by the author) methodology has been verified on the basis of maintenance data of three companies, that manage technical network systems (water supply system, sewage system, heating system). The second part of the article includes interpretation of the findings of assessment of exploitation policy of analyzed technical network systems, as well as indications of possible proceedings into studied companies, in the field of maintenance works realization.

Key words: *exploitation policy, numerical taxonomy, technical network systems, maintenance management*

INTRODUCTION

The results presented in the article, are a continuation of research conducted by the author on ways to assess the functioning of the technical staff in industrial and service companies. The starting point is method to assess the exploitation policy developed by the author, which was described in [19]. In this regard:

a) it was defined the scope of exploitation policy term, as a set of features and their representation for the needs of realization of decision-making situations within the exploitation decision-making process,
b) it was assumed and justified, that as complete description of exploitation policy has a multi-faceted nature and can be achieved in the way of building models depicting the relationship between technical, organizational and economic aspects of operating technical systems and functioning maintenance staff,
c) it was assumed and justified, that quantitative assessment of exploitation policy should be carried out on the basis of a multi-dimensional set of values, resulting from the realization of maintenance works of certain categories, in terms of key features describing the most important aspects of functioning maintenance staff,
d) it was developed a method for quantitative assessment of exploitation policy, which involves taxonomic transformation of key feature values (describing in a distributed manner different parts of the exploitation processes), in the synthetic variable,
e) it was assumed and justified, that obtained synthetic variable can be interpreted as a specific resultant of assessment of exploitation policy in the field of concerned events and exploitation processes,
f) developed method to assess the exploitation policy allows to carry out a variant comparative analysis, which impacts the exploitation decision-making process.

Later in this article, developed and described in the [19] a multi-faceted method to assess the exploitation policy has been verified in the conditions of functioning three distinct technical network systems: the water supply system, the sewage system and the heating system.

The article includes results of statutory research no. BK 223/ROZ3/2015, carried out at the Institute of Production Engineering of the Silesian University of Technology. Included results are one of the key parts of the author's research on the methodology of modelling exploitation decision-making process using scenario methods.

EXPLOITATIN SPECIFICITY OF TECHNICAL NETWORK SYSTEMS

Technical network systems are included in the infrastructure, which is the basis for functioning engineering sectors of industrial companies and municipal services [4, 9]. Typical examples of the technical network systems, which are the research subject, included in this article, are: the water supply system, the sewage system and heating system [10, 11, 27].

Realization of exploitation processes into technical network systems are the subject of numerous works and scientific publications, including the technical aspects of their construction [1, 5, 10, 11, 27, 36], or maintenance procedures [3, 6, 7, 8, 9, 24, 25]. It should also be pointed out attempts to develop and verify the economic models describing cost-effectiveness of operation of technical network systems, as well as the desirability and possibility of renewal [12, 28, 29, 32]. Especially important areas of published research papers is a trenchless early identification of network leaks and damage of its armament, as well as statistical analysis of wear (reliability assessment), in the material aspect, or in view of influences with external environment [13, 18, 22, 31, 33, 34]. As a result of conducted detailed literature analysis, it was observed:

- significantly higher research interest of exploitation processes in the phase – before the event (including identification, location and assessment of damages causes), than in the phase – after the event (including maintenance procedures, organization and optimization of maintenance resources),
- assessment of the effects of exploitation decision-making process is characterized by uniqueness for each class of technical network systems, concerned here; this results in a large variety of measures, built on an individual basis and interpreted within different frames of reference.

Typical modelling ways of describing exploitation policy (including: model of areas and tasks of realization of management functions [2, 14], Business Centered Maintenance model – BCM [16, 20], Total Productive Maintenance model – TPM [23, 30], or graph model [17, 35] are typical for the technical productive systems. The specificity of exploitation of technical network systems [13, 15, 18], makes it necessary to include the constraints, both in developing exploitation policy models, as well as in selection of features forming the basis for assessing its effectiveness. The key problem is the difficult maintenance access to technical network systems, restricting the possibility of acquiring the feature values, which constitute the core of the assessment, in terms of the above mentioned models. Hence, presented here approach is based on the assumption of:

- common features within the different categories of technical network systems, determining the possibility of development of exploitation policy according to similar technical-organizational-economic principles,
- exploitation specificity of technical network systems, causing the need to take account of restrictions, that influence the range of features necessary to take into account, as well as the possibility of their systematic acquiring.

Analysis of acquired data collection of maintenance management works, confirmed that a sufficient set of key features, allowing you to define quantitative image of exploitation policy, includes: cost, time and quantity of completed maintenance works. A separate issue of research in this area remains to develop typical pattern models, as a statistical measure of the similarity of features, which should be subject to comparative assessment with acquired exploitation data collections [26].

TAXONOMIC ASSESSMENT OF EXPLOITATION POLICY OF ANALYZED TECHNICAL NETWORK SYSTEMS

On the basis of developed method to assess the exploitation policy [19], there was carried out a taxonomic assessment of functioning the maintenance organizations in the selected three companies managing technical network systems, including: water supply system, sewage system, heating system[1].

Taking into account the specificity and the circumstances of functioning of technical network systems, it was assumed, that the construction of taxonomic model will be based on four categories of maintenance works, and the three key features of exploitation policy, whose interpretation is presented in Table 1.

Taking into account the content of Table 1, scheme of arrangement of input values of taxonomic model, takes the form shown in Table 2.

Table 1

The categories of maintenance works and the key features of exploitation policy, for the needs of developing the taxonomic model of the exploitation policy assessment

Categories of maintenance works	Key features of exploitation policy
Inspections, intended to control and assess the degree of wear or damage of components of the network, armament or engineering equipment.	**The cost of completed maintenance works**, interpreted in the economic area and expressing the level of resource use, especially material, complemented by the value of workload of all works of the type in the analyzed period
Maintenances whose task is to maintain the network in operation.	**The time of completed maintenance works**, interpreted in the technical area and expressing the level of workload of all maintenance works of the type in the analyzed period
Repairs, whose aim is to remove the effects of unintended events.	**Quantity of completed maintenance works,** interpreted in organizational area and expressing the resource potential of maintenance organization
Overhauls, whose task is to bring the object to the functional (restoration of the initial exploitation potential).	

Table 2

A set of input features of the exploitation policy assessment model of the technical network systems

		Cost	Time	Quantity
	W/B	w_1	w_2	w_3
Inspections	b_1	ch_{11}	ch_{12}	ch_{13}
Maintenances	b_2	ch_{21}	ch_{22}	ch_{23}
Repairs	b_3	ch_{31}	ch_{32}	ch_{33}
Overhauls	b_4	ch_{41}	ch_{42}	ch_{43}

[1] Due to the range of information, that can be a strategic value, author deliberately omitted the names of the surveyed companies. It does not infuence the value of the analyze, in any way.

In the following works on the taxonomic assessment of exploitation policy of selected technical network systems, there was assumed a common research procedure, consisting of the following steps:

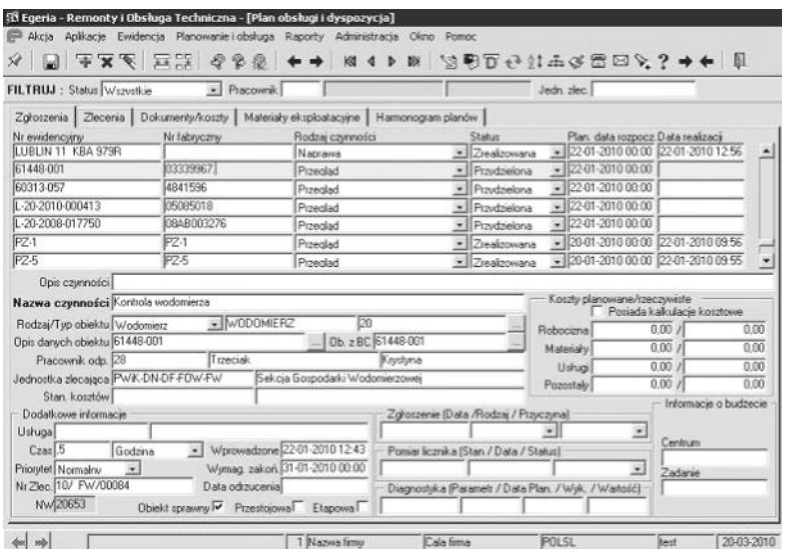
- identification of data sources and their origin locations, for the purpose of ordering value of analyzed features, separately for each technical network system,
- performing taxonomic assessment of exploitation policy, according to the procedure described in [21],
- interpretation of the results, in individual perspective, as well as in a comparative manner, in relation to other analyzed technical network systems.

The diagnosis of functioning of the maintenance organizations in the analyzed companies, showed wide variations in the ways of acquiring, collecting and processing data from maintenance works. These variations can be represented by the following conclusions and observations:

1. The range of data collected. In this regard, it was noted:
   - full repeatability of attributes allowing identification of three key features, ie cost, time and quantity of completed maintenance works, in the data acquired structure, for all three analyzed technical network systems,
   - high freedom of interpretation of maintenance works categories, which manifested itself in significant differences of organizing tasks with similar specificity and range of realization (eg. task on clearing drainage channel in one case was maintenance, and repair in another),
   - clear and unambiguous distribution of the collected data to location areas, such as zones or districts.
2. The ways of acquiring data about progress and results of the maintenance works realization. This aspect concerns organizational and technical differences of maintenance works processes, with a focus on documenting stage. It was observed the practice of two different procedures, which had a potential impact on the range and quality of the acquired data, namely:

a) slave (current) data acquisition from individual (single) stage of maintenance works,
b) as-built (final) data acquisition from all (all at once) stages of maintenance works.

a)



b)

Karta pracy

Pieczęć	Miesięczna karta pracy za miesiąc	nr 2	Pracownicy - stanowiska:	łączna ilość godzin
ZC-1 Remonty		Kwiecień 2013	warsztat WP	784

L.p.	LOKALIZACJA ROBÓT, OPIS ROBÓT	Sumaryczna ilość godzin pracy	Stanowisko kosztów
1	Wymiana zaworu DN 150 przyłącze od ul. Kujawskiej (zdjęcie pokrywy studzienki, wymiana zaworu, montaż pokrywy)	30	538-16-118-197
2	Wykonanie odpowietrzenia pompy przewałowej nr 1 oraz wymian oleju	35	538-16-117-173
3	Przeniesienie naciągu głównego taśmociągu nawęglania WR (przygotowanie materiału likwidacja starego naciągu montaż nowego oraz wykonanie ruchu próbnego)	112	538-13-255-120
4	Wymiana zaworów odcinających pompę podgrzewacza powietrza WR nr 1	8	538-11-251-012
5	Wymiana zaworów odcinających pompę podgrzewacza powietrza WR nr 4 oraz wykonanie odcięcia od strony kolektora	16	538-11-254-058
6	Wykonanie wpięcia instalacji osuszacza do wody grzejnej DEMI (zakończono prace), oraz wykonano piankowania połączeń preizolacyjnych od budynku stacji sorbentu do osuszacza	60	538-14-707-307
7	Wykonanie odwodnienia rurociągu zasilającego WR nr 1	8	538-11-251-010
8	Remont odżużlacza WR nr 1 strona lewa i prawa (płaskownik ślizgowy, rolki, wymiana taśmy zgrzebłowej prawa strona)	70	538-14-256-133

Mistrz Kierownik Dyrektor

Fig. 1 Examples of data collecting techniques for the taxonomic assessment of the exploitation policy: a. IT technique – maintenance module of ERP system, b. traditional technique – monthly job card

Each of these means has its own benefits, which should be interpreted individually, in terms of the available potential of maintenance organizations (including availability of personnel, equipment and information-computing). It should also be pointed out some hazards, that in the case of „a" variant, may result in reduction of the effectiveness of realization of maintenance works, under certain conditions of human potential deficiency. In the case of „b" variant – there is a risk of conscious or unconscious omission or misinterpretation of facts and events that took place.

3. The data collection techniques. In the analyzed companies there were identified two different techniques used to collect data and information on the completed maintenance works:
   - computer technique, in the form of a network computer system, based on a database used to collect data and information on the realization of maintenance work, and in addition, designating and controlling procedures for acquisition,
   - traditional technique, in the form of cards for maintenance works or reporting books, supplemented with statement and graphs with the use of spreadsheets or word processors.

Examples of two data collection techniques, for the purpose of developing taxonomic exploitation policy assessment models, is shown in Fig. 1. Synthetic summary of key aspects of acquiring, collecting and processing data on performed and completed maintenance works, with regard to the analyzed technical network systems, is summarized in Table 3.

The analysis of data and information on the realization of maintenance works, showed the need to organize values of key features, for the purpose of taxonomic assessment of exploitation policy. To this end, for all three analyzed technical network systems:

- there was identified and determined three key features: cost, time and quantity of completed maintenance works,
- there was identified and determined four categories of maintenance works (inspections, maintenances, repairs, overhauls) and there was assigned works to them, in terms of range, expected progress and expected effects of the completion,
- there was identified and determined one year, as a uniform date range of acquired data, coincides with complete maintenance cycle for inspection and maintenance tasks,
- there was eliminated or corrected erroneous entries of acquired and collected data, which could affect the results of analyzes improperly and significantly.

Based on prepared data sets, coming from the annual realization of maintenance works (2013 year), calculations were carried out, using the taxonomic model, proposed and described in [21]. The results of calculations, in the form of synthetic measures and absolute geometric distances, for particular categories of maintenance works, are summarized in Table 4.

The results of assessment of exploitation policy, based on a developed taxonomic model, for three analyzed technical network systems, is shown in Fig. 2 (in the collective system: tabular and graphical).

PATTERN MODELS (VARIANTS) OF EXPLOITATION POLICY ASSESSMENT

Interpretation of the results of taxonomic assessment of exploitation policy, for analyzed technical network systems, includes:

- assessment of features structure in a percentage, divided into categories of maintenance works,
- assessment of determined values of synthetic measures, for particular categories of maintenance works,
- assessment of taxonomic geometric location, for particular categories of maintenance works, in absolute value – distances of particular categories from the beginning of the coordinate system, as well as in relative terms – the mutual distances between particular categories,
- assessment of taxonomic geometric distances from the beginning of the coordinate system, for particular categories of maintenance works.

Table 3

Summary of key aspects of data acquiring, collecting and processing in the range to maintenance work in relation to the analyzed technical network systems

Aspect	Water supply system	Sawage system	Heating system
The scope of data collection	Very high coherence and clarity of data and information	Medium coherence and clarity of data and information	Structural irregularity the scope of data and information
	Division of maintenance activity area on pressure zones	Division of maintenance activity area on district	Division of maintenance activity area on zone
	Consistent use four categories of maintenance works	inonsistent use four categories of maintenance works	Consistent use four categories of maintenance works
The methods of data acquisition	Inspections, maintenances and repairs - as - built	As - built	As - built
	Overhauls - trailing		
The techniques of data collection	Database of „overhaul" module of ERP system	Traditional technique - repairs, overhauls	Traditional technique - heating network together with the armament
		Computer technique - inspections, maintenances	Computer technique - heating plant

Table 4

Summary of taxonomic measure values of assessment of exploitation policy for analyzed technical network systems

Categories of maintenance works	Water supply system		Sewage system		Heating system	
	Synthetic measure	Geometric distance	Synthetic measure	Geometric distance	Synthetic measure	Geometric distance
Inspections	0.0853	0.8569	0.0866	0.9988	0.0962	1.5849
Maintenances	0.1814	0.6246	0.3340	0.3298	0.0222	1.8227
Repairs	0.2166	0.7810	0.1224	0.8207	0.0903	1.4773
Overhauls	0.0531	1.2738	0.2472	0.5803	0.0423	1.7000

Table 5

Assumptions and criteria for the construction patterns of exploitation policy assessment

The initial parameters

- values of features (cost, time and quantity) for 1000 maintenance works,
- classes of complexity of the maitenance works,
- 4 categories of the maintenance works (inspections, maintenances, repairs, overhauls).

The intended effect - the package of patterns

- the pattern model of brakdown strategy - „waiting for event" without taking preventive or ahead actions,
- the pattern model of preventive strategy - overtaking the occurrence of unintended events, taking into account the statistical reliability criteria,
- the pattern model of predictive strategy - conditional realization of the necessary maintenance works, based on the results of the ongoing assessment of technical objects.

The internal structure of patterns built

- dominant influence of the type of the work categories, which are important in a given pattern of exploitation policy,
- less or insignificant influence of the type of the work categories, which are present, by , in small quantities and a small range, in a given pattern of exploitation policy.

Water supply system	cost		time		quantity	
Inspection	151 819,73 zł	14,42%	49706	84,80%	6328	65,25%
Maintenance	146 773,18 zł	13,94%	3082	5,26%	1544	15,92%
Repair	192 134,67 zł	18,25%	2187	3,73%	530	5,47%
Overhaul	561 928,82 zł	53,38%	3640	6,21%	1296	13,36%
Sum	1 052 656,40 zł	100,00%	58615	100,00%	9698	100,00%

Sewage system	cost		time		quantity	
Inspection	140 123,03 zł	30,35%	80072	44,06%	16494	57,10%
Maintenance	32 716,00 zł	7,09%	22290	12,27%	2519	8,72%
Repair	188 450,00 zł	40,81%	48235	26,54%	8851	30,64%
Overhaul	100 459,00 zł	21,76%	31129	17,13%	1022	3,54%
Sum	461 748,03 zł	100,00%	181726	100,00%	28886	100,00%

Heating system	cost		time		quantity	
Inspection	99 150,00 zł	4,36%	9915	16,28%	276	29,71%
Maintenance	286 575,00 zł	12,59%	19105	31,37%	253	27,23%
Repair	853 667,00 zł	37,51%	17073	28,04%	154	16,58%
Overhaul	1 036 363,00 zł	45,54%	14805	24,31%	246	26,48%
Sum	2 275 755,00 zł	100,00%	60899	100,00%	929	100,00%

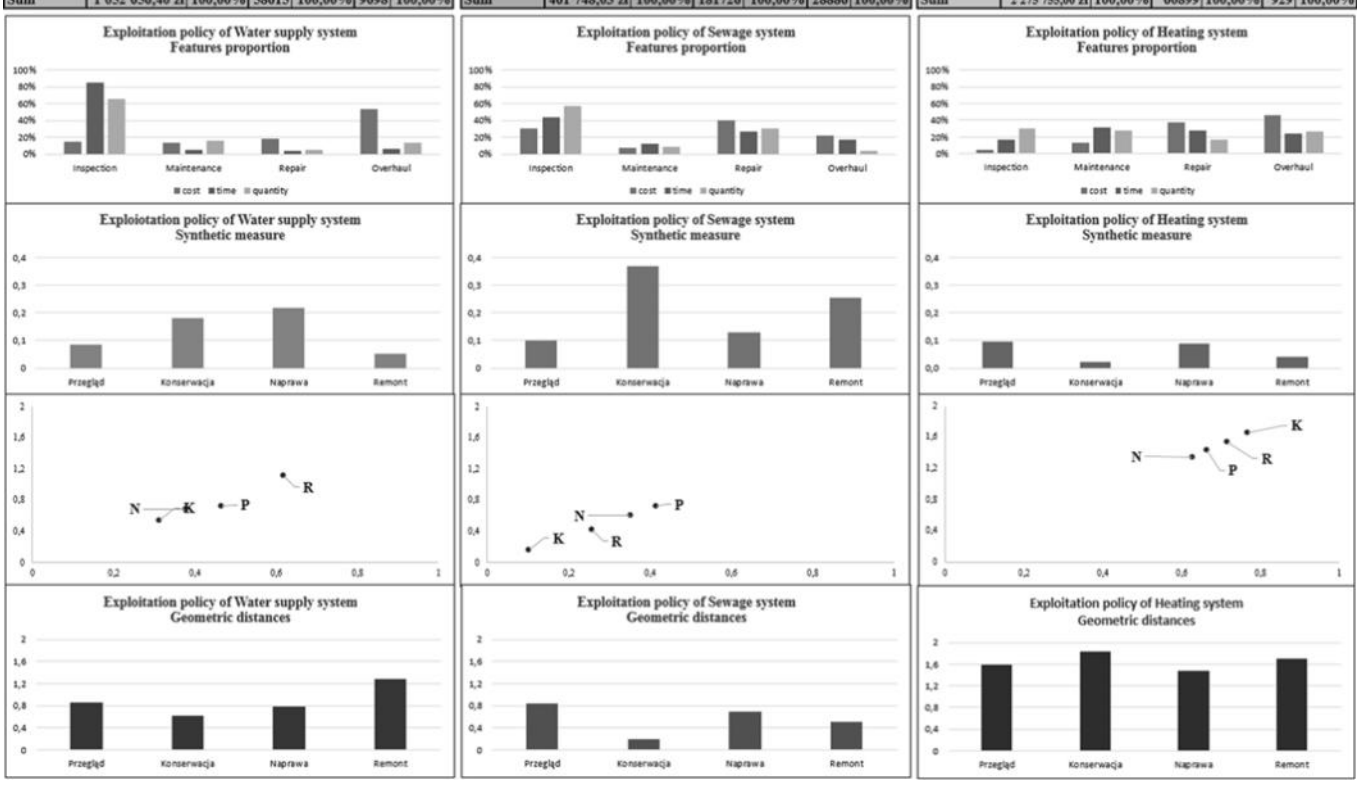


Fig. 2 Tabular – graphic summary of the measures of taxonomic model of assessment of exploitation policy for three analyzed technical network systems

Carrying out the analysis according to the above guidelines is possible on a comparable basis, with the use of definable patterns (variants), describing exploitation policy in a quantitative manner (taxonomically). The process of developing pattern models included:

a) defining assumptions and preliminary parameters, uniformly for all three analyzed technical network systems,
b) developing and verifying pattern structures of maintenance works, individually for each of analyzed technical network systems,
c) synthesizing data developing aggregated structures of maintenance works, uniformly for all three analyzed technical network systems,
d) developing a set of taxonomic pattern models of exploitation strategy, based on the structure of maintenance works, uniformly for all three analyzed technical network systems.

The process of developing pattern models, which was carried out on an analysis of historical data and expert evaluation, taked into account assumptions – summarized in Table 5.

Based on the assumptions, having regard to calculations in accordance with [21], there was prepared:

a) maintenance works structure of the pattern models, which is listed in Table 6,
b) a set of taxonomic pattern models, which is shown in Fig. 3 (tabular and graphical way).

INTERPRETATION OF THE RESULTS OF VARIANT ASSESSMENT OF EXPLOITATION POLICY OF ANALYZED TECHNICAL NETWORK SYSTEMS

Taxonomic assessment of exploitation policy of analyzed technical network systems showed high diversity of the structure of completed maintenance works (Fig. 2), in particular:

1. Exploitation policy, carried out for the analyzed water supply system, is characterized by:
   - lack of distinct absolute taxonomic domination of any categories of maintenance works,
   - the most significant category of repair works (the smallest value of synthetic measure with the largest values of geometric distance – the resultant distance from the beginning of the coordinate system),
   - large quantity and time-consuming diagnostic works (inspections), with their insignificant economic value, which image are the average absolute values of synthetic measure and geometric distances,
   - middle dispersion of particular categories of maintenance works (medium mutual geometrical distances), reflecting in highlighted, but not distinct, relative dominance of overhaul works.

Table 6

Taxonomic maintenance works structure, for developing pattern models of exploitation strategy for analyzed technical network systems

Pattern model of breakdown strategy	**Inspections** weight: 0.05				**Maintenances** weight: 0.15				**Repairs** weight: 0.7				**Overhauls** weight: 0.1			
Total quantity of works **1000**	Quantity 50		Cost [PLN]	Time [hours]	Quantity 150		Cost [PLN]	Time [hours]	Quantity 700		Cost [PLN]	Time [hours]	Quantity 100		Cost [PLN]	Time [hours]
Complexity level of works: 1	0.5	25	500.00	6.25	0.5	75	1500.00	18.75	0.05	35	700.00	8.75	0.5	50	2500.00	75.00
Complexity level of works: 2	0.2	10	250.00	5.00	0.2	30	750.00	15.00	0.1	70	1750.00	35.00	0.2	20	3000.00	40.00
Complexity level of works: 3	0.15	8	375.00	7.50	0.15	23	1125.00	22.50	0.15	105	21000.00	105.00	0.15	15	3750.00	60.00
Complexity level of works: 4	0.1	5	250.00	5.00	0.1	15	750.00	15.00	0.2	140	35000.00	140.00	0.1	10	5000.00	40.00
Complexity level of works: 5	0.05	3	250.00	2.50	0.05	8	750.00	7.50	0.5	350	175000.00	350.00	0.05	5	7500.00	20.00
Sum	**1**	**50**	**1625.00**	**26.25**	**1**	**150**	**4875.00**	**78.75**	**1**	**700**	**233450.00**	**638.75**	**1**	**100**	**21750.00**	**235.00**

Pattern model of preventive strategy	**Inspections** weight: 0.1				**Maintenances** weight: 0.55				**Repairs** weight: 0.05				**Overhauls** weight: 0.3			
Total quantity of works **1000**	Quantity 100		Cost [PLN]	Time [hours]	Quantity 550		Cost [PLN]	Time [hours]	Quantity 50		Cost [PLN]	Time [hours]	Quantity 300		Cost [PLN]	Time [hours]
Complexity level of works: 1	0.5	50	1000.00	12.50	0.05	28	550.00	6.88	0.5	25	500.00	6.25	0.05	15	750.00	22.50
Complexity level of works: 2	0.2	20	500.00	10.00	0.1	55	1375.00	27.50	0.2	10	250.00	5.00	0.1	30	4500.00	60.00
Complexity level of works: 3	0.15	15	750.00	15.00	0.15	83	4125.00	82.50	0.15	8	15000.00	7.50	0.15	45	11250.00	180.00
Complexity level of works: 4	0.1	10	500.00	10.00	0.2	110	5500.00	110.00	0.1	5	12500.00	5.00	0.2	60	30000.00	240.00
Complexity level of works: 5	0.05	5	500.00	5.00	0.5	275	27500.00	275.00	0.05	3	125000.00	2.50	0.5	150	225000.00	600.00
Sum	**1**	**100**	**3250.00.00**	**52.50**	**1**	**550**	**39050.00**	**501.88**	**1**	**50**	**4750.00**	**26.25**	**1**	**300**	**271500.00**	**1102.50**

Pattern model of predictive strategy	**Inspections** weight: 0.6				**Maintenances** weight: 0.2				**Repairs** weight: 0.05				**Overhauls** weight: 0.15			
Total quantity of works 1000	Quantity 600		Cost [PLN]	Time [hours]	Quantity 200		Cost [PLN]	Time [hours]	Quantity 50		Cost [PLN]	Time [hours]	Quantity 150		Cost [PLN]	Time [hours]
Complexity level of works: 1	0.05	30	600.00	7.50	0.05	10	200.00	2.50	0.5	25	500.00	6.25	0.5	75	3750.00	112.50
Complexity level of works: 2	0.1	60	1500.00	30.00	0.1	20	500.00	10.00	0.2	10	250.00	5.00	0.2	30	4500.00	60.00
Complexity level of works: 3	0.15	90	4500.00	90.00	0.15	30	1500.00	30.00	0.15	8	15000.00	7.50	0.15	23	5625.00	90.00
Complexity level of works: 4	0.2	120	6000.00	120.00	0.2	40	2000.00	40.00	0.1	5	12500.00	5.00	0.1	15	7500.00	60.00
Complexity level of works: 5	0.5	300	30000.00	300.00	0.5	100	10000.00	100.00	0.05	3	125000.00	2.50	0.05	8	11250.00	30.00
Sum	**1**	**600**	**42600.00**	**547.50**	**1**	**200**	**14200.00**	**182.50**	**1**	**50**	**4750.00**	**26.25**	**1**	**150**	**32625.00**	**352.50**

Pattern model of breakdown strategy	cost		time		quantity	
Inspection	1 625,00 zł	0,62%	26,25	2,68%	50	5,00%
Maintenance	4 875,00 zł	1,86%	78,75	8,05%	150	15,00%
Repair	233 450,00 zł	89,21%	638,75	65,26%	700	70,00%
Overhaul	21 750,00 zł	8,31%	235,00	24,01%	100	10,00%
Sum	261 700,00 zł	100,00%	978,75	100,00%	1000	100,00%

Pattern model of preventive strategy	cost		time		quantity	
Inspection	3 250,00 zł	1,02%	52,50	3,12%	100	10,00%
Maintenance	39 050,00 zł	12,26%	501,88	29,82%	550	55,00%
Repair	4 750,00 zł	1,49%	26,25	1,56%	50	5,00%
Overhaul	271 500,00 zł	85,23%	1102,50	65,50%	300	30,00%
Sum	318 550,00 zł	100,00%	1683,13	100,00%	1000	100,00%

Pattern model of predictive strategy	cost		time		quantity	
Inspection	42 600,00 zł	45,23%	547,50	49,38%	600	60,00%
Maintenance	14 200,00 zł	15,08%	182,50	16,46%	200	20,00%
Repair	4 750,00 zł	5,04%	26,25	2,37%	50	5,00%
Overhaul	32 625,00 zł	34,64%	352,50	31,79%	150	15,00%
Sum	94 175,00 zł	100,00%	1108,75	100,00%	1000	100,00%

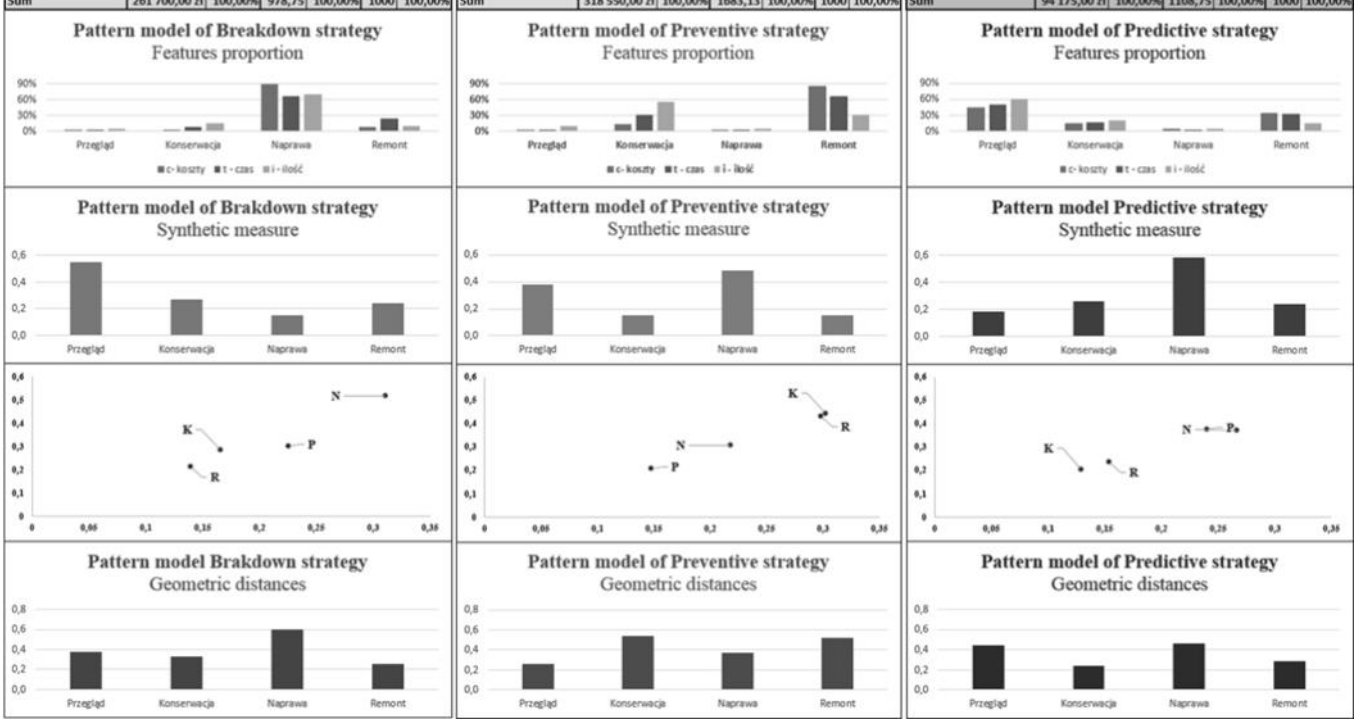


Fig. 3 Tabular-graphic presentation of taxonomic measures of pattern models of exploitation strategy for analyzed technical network systems

According to the above interpretation, it should be noted, that the exploitation policy carried out in relation to the analyzed water supply system is a preventive of diagnostic type – with significant share of corrective works, induced by criterial assessment of the technical condition (significant quantity and time of inspections, at low cost of these works).

2. Exploitation policy, carried out for the analyzed sewage system, is characterized by:
   - fairly distinct taxonomic absolute dominance of two categories of maintenance works, that is, inspections and repairs,
   - small (the smallest in the case) taxonomy importance of maintenance works,
   - medium dispersion of categories of maintenance works, with less distance the whole concentration from the beginning of the coordinate system.

In the taxonomic sense, it is difficult to unambiguous interpretation of exploitation policy carried out for the analyzed sewage system. Firstly, there is a fairly clear and comparable importance of two categories of maintenance works, ie inspections and repairs, which are opposite themselves from a methodological point of view. Secondly, small dispersion of the whole concentration, with a little distance from the beginning of the coordinate system indicates a correct, balanced and exploitationally reasonable arrangement of works within particular categories. The above arguments suggest acceptation of this maintenance system as an interim situation, with a great need and possibility to optimize.

3. Exploitation policy, carried out for the analyzed heating system, is characterized by:
   - lack of distinct absolute taxonomic domination of any categories of maintenance works,
   - greater taxonomic significance of a pair of work categories: maintenances and overhauls, with less significance of pair of work categories: inspections and repairs,
   - little distinct taxonomic relative dominance of any categories of maintenance works (ie. low dispersion), with a great distance the whole concentration from the beginning of the coordinate system.

The exploitation policy carried out in relation to the analyzed heating system is a preventive of normative type. This is indicated by balanced arrangement of all types of maintenance works, as well as taxonomic dominance of works (maintenances and overhauls), frequency and range of which is mainly based on the guidelines of reliability tests.

Synthesizing the results of the research, it should be noted, that none of the analyzed cases indicates the dominant category of maintenance works, which unequivocally could constitute nature of exploitation policy. The results of the calculations, and mainly their visualization (Fig. 2), show a wide range of key features (cost, time, quantity of completed maintenance works), making it difficult or impossible to unequivocally identify the specificity of exploitation policy. Therefore, it is necessary to referring the key feature values of analyzed technical network systems to the corresponding analogous features of pattern models of exploitation policy (Fig. 3) and thus, carring out comparative procedures, according to (1) [21]:

$$Ps_{\min} = \min_{1\geq j\geq 3}\left|\sum_{i=1}^{4}\left(Ss_i - Sw_{ij}\right)\right|$$
$$Pd_{\min} = \min_{1\geq j\geq 3}\left|\sum_{i=1}^{4}\left(Ds_i - Dw_{ij}\right)\right| \quad (1)$$

where:
Ps_{min} - the result of comparing assessment of exploitation policy of technical system with positioning pattern, in the field of synthetic measure, for particular categories of maintenance works,
Pd_{min} - the result of comparing assessment of exploitation policy of technical system with positioning pattern, in the field of geometric distance, for particular categories of maintenance works,
Ss_i - synthetic measure of assessment of exploitation policy of technical system, for particular categories of maintenance works,
Sw_i - synthetic measure of positioning pattern of assessment of exploitation policy, for particular categories of maintenance works,
Ds_i - geometric distance value of assessment of exploitation policy, for particular categories of maintenance works,
Dw_i - geometric distance value of positioning pattern of assessment of exploitation policy, for particular categories of maintenance works.

Models of exploitation policy of analyzed technical systems take the specificity and nature of positioning patterns, with the highest taxonomic similarity, ie in the case of the smallest resultant values of absolute differences for the corresponding synthetic measures and geometric distances. The results of the calculations are presented in Table 7.

The calculations and comparative analysis in terms of the key features of exploitation policy, confirmed (Table 7):
- taxonomic similarity of exploitation policy of water supply system to the preventive strategy pattern model,
- taxonomic similarity of exploitation policy of sewage system to the breakdown strategy pattern model,
- taxonomic similarity of exploitation policy of heating system to the preventive strategy pattern model.

It should also be noted, that analyzed technical network systems deviate taxonomically from the pattern models (in some cases – significantly) (Fig. 4).

On the one hand, it justifies the conclusion, formulated earlier, about the lack of clear guidelines, concerning distinct nature of exploitation policy of analyzed technical network systems. On the other hand, it indicates a high potential area for a possible modifications. According to the author, such modification should be carried out within and between different categories of maintenance works, and its effect can be minimization of particular differences.

Table 7
Comparison of resultant values of taxonomic assessment of exploitation policyof analyzed technical network systems against the positioning patterns

Technical Network System	Pattern model of breakdown strategy		Pattern model of preventive strategy		Pattern model of predictive strategy	
	Psmin	Pdmin	Psmin	Pdmin	Psmin	Pdmin
Water supply system	0.7898	1.9709	0.6944	1.8440	0.7275	2.1056
Sewage system	0.5545	1.1652	0.9385	1.4516	0.6473	1.2987
Heating system	0.9374	5.0194	0.9194	4.8924	1.0128	5.1540

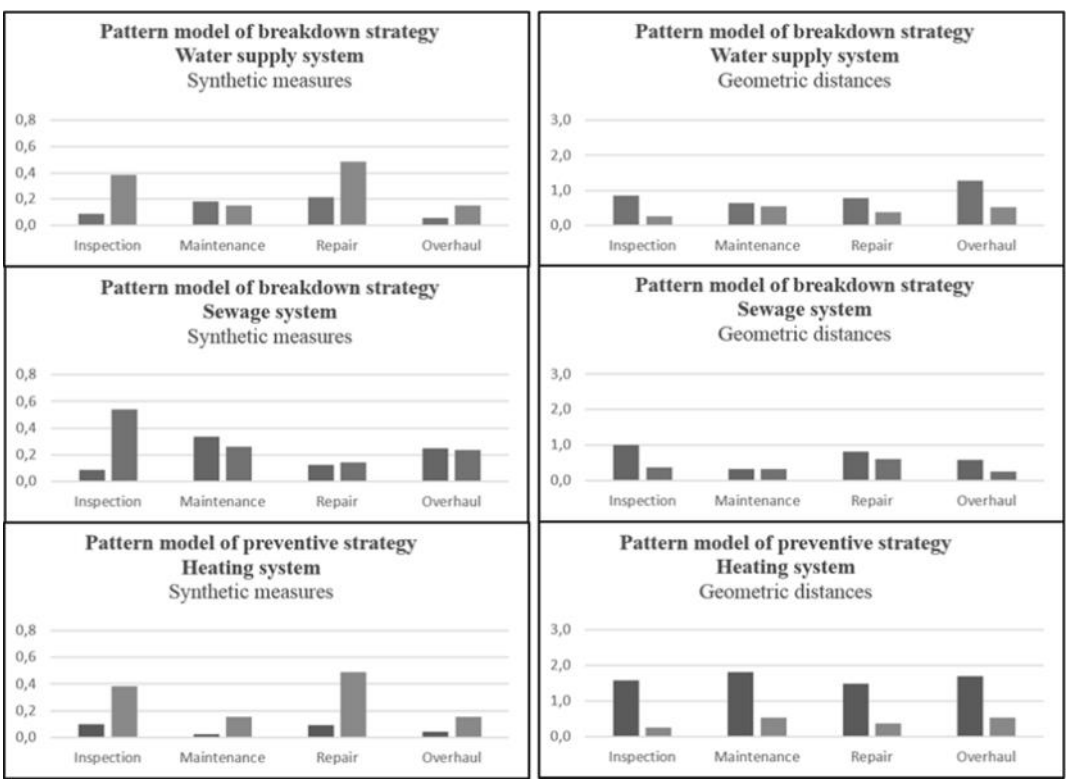


Fig. 4 Graphical comparision of taxonomic models of exploitation policy of analyzed technical network systems against the pattern models

CONCLUSIONS

Verification tests, with regard to the possibility of using the developed methodology for taxonomic modelling and assessment of exploitation policy, performed under conditions of functioning of selected technical network systems, confirm the need for an assessment both in the variant – comparative, as well as on a time window.

Positive results tend to continue of research in these areas, which, the author believes, require clarification or further development, both in the model and the application approach. These studies should aim to clarify the scope of applicability and the level of effectiveness of the developed methodology in the sense of its versatility. For this purpose, based on developed assessment models of exploitation policy, it is necessary to carry out analytical and expert interpretation of the results of taxonomic calculations, for possibly large quantity of companies, which manage technical network systems. This will allow modification/ verification of developed methodology, including evaluation/increase its accuracy in view of posed and solved exploitation decision problems.

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