13

ANALYTICAL MODEL OF THE EXPLOITATION POLICY ASSESSMENT OF TECHNICAL NETWORK SYSTEMS - CASE STUDY

13.1 INTRODUCTION

Reliable valuation of exploitation tasks is one of the key criteria of proper functioning of the technical staff in enterprises. This means the need to determine the values of the selected features, and consequently the opportunity to shape the decision-making processes related to the exploitation policy.

There are many mathematical models underlying the quantitative assessment of the way and the scope of exploiting technical systems. The great diversity, as well as the organizational and economic specificity of managing and documenting the maintenance process in particular enterprises affects the individualization of developed and used in practice computational solutions.

The article includes a discussion on the possible ways of assessing the exploitation policy in terms of functioning technical network systems.

13.2 REVIEW THE METHODS OF EXPLOITATION ASSESSMENT OF THE TECHNICAL SYSTEMS

The sets of exploitation measures are the subject of many publications, as:

- separate literature items, containing an ordered list and characteristics of specific measures [6, 7],
- components of methods and tools for maintenance management, in the form of description of the exploitation strategy or maintenance management system [2, 8],
- individual or universal ways of interpretation and construction of complex multi-element models of exploitation measures [1, 4].

Measures applied in enterprises practice are usually to evaluate the exploitation effectiveness. They are based on two groups of components:

1. Computing technical components, which express in a direct way, the share of a technical object in exploitation activities. Indicator values calculated in this area, are determined by the time of object „location” in a certain condition class. Hence,

they are the basis for assessment of the decisions concerning the technical and organizational activities of the maintenance staff.

2. Computing economic components, which express in a indirect way, the share of a technical object in exploitation activities. Measures in this category allow you to determine the cost of functioning of technical systems in a specific organizational environment. In conjunction with the analysis of the variability of these values in time, it corresponds to the assessment of the decisions, in the field of exploitation activity.

Efficiency measures, being the assembly of the above components, describe the level of realization of exploitation policy, mostly in a comprehensive and aggregate manner. In this case, mathematical models are resultants in relation to the simple measures used. In this area can be distinguished [3, 5].

- the exploitation availability indicator:

$$A = \frac{MTBF}{MTBF + MFOT} \tag{13.1}$$

where:
$MTBF$ – mean time between failures,
$MFOT$ – mean force outage time.

This expression represents the relationship between reliability and serviceability. Expected availability assumes maximization of $MTBF$, while minimization of $MFOT$.

- the exploitation efficiency indicator:

$$E = \frac{MTBF}{MTBF + MTTR} \tag{13.2}$$

where:
$MTTR$ – mean time to repair.

With regard to the characteristics of technical systems, this expression, like the previous one, represents the relationship between reliability and serviceability. However, in this case, the serviceability takes a slightly different interpretation, because it more reflects the efficiency and reaction rate, but in the organizational aspect. These conditions cause the link the above relationship with the efficiency, Particularly with regard to the assessment of the level of functioning of technical staff.

- OEE as the most important element of the quantitative assessment of the TPM strategy, which expresses the overall efficiency of maintenance using three main factors: availability, operational efficiency and quality (Table 13.1).

Table 13.1 Components of the OEE

Availability	**Operational efficiency**	**Quality**
$D = \frac{t_d - t_p}{t_d}$ (3)	$E = \frac{t_c \cdot n}{t_o}$ (4)	$J = \frac{n - d}{n}$ (5)
t_d - loading time, t_p - downtime.	t_c - theoretical cycle time, n - processed amount, t_0 - operating time.	n - processed amount, d - defect amount.
$\boldsymbol{OEE = D \cdot E \cdot J}$		

Source: [8]

Due to the high flexibility, OEE is also used in those companies that do not implement the TPM strategy. Because of the method of calculating the OEE (the product of partial indicators), it is not important the absolute value of the indicator, but conclusions from the way of obtaining. Hence, the mathematical interpretation of its value should be geometrical. In particular, by presenting OEE as a vector in 3D, it is possible to formulate conclusions and decisions relating to its absolute value, the impact of the individual factors on the resultant and the direction and level of the change.

A common part of the above models is a multifaceted comprehensive set of measures, which are the basis of the assessment. Based on the author's verification of these models, in view of their practical applicability for the assessment of the exploitation policy, it was noted that under complex organizational and technical conditions of exploitation systems and not very precisely formulated potential managers' expectations, the multiplicity and diversity of the measures, it may lead to:

- ambiguity of measures interpretation, in terms of influence of individual factors on the exploitation effectiveness,
- unreasonably substantiated highlighting selected aspects, in the context of the exploitation policy of the enterprise,
- unreasonable argument of higher quality of the resulting assessment of the exploitation policy based on more measures.

It was also noted obstacles and organizational constraints in obtaining and collecting complete (reliable) data resource, as a basis to develop verifiable models of the exploitation indicators. These arguments allowed to specify assumptions about the possibility of building such a assessment model, which should represent, in a quantitative and current way, level and change of the exploitation policy, expressed by the features of the key, but different, interpretation meaning for the examined object - the maintenance organization. The assessment of the exploitation policy can be realized, based on a multi-dimensional set of values, describing the maintenance works of selected categories, including key features describing the activities of the maintenance organization.

13.3 THE ASSESSMENT OF THE EXPLOITATION POLICY OF TECHNICAL NETWORK SYSTEMS - CASE STUDY

Technical network systems are part of infrastructure constituting the basis for the functioning of engineering sectors of industrial and municipal enterprises. Through the technical network systems there are delivered services in the form of different types of media to recipients of different categories.

Analysis of data and information sets, as well as the assessment of existing concepts concerning goals and criteria of exploitation decisions, make a legitimate assumption, That a sufficient set of key features to define a quantitative image of exploitation policy, includes: time, costs and quantity of completed maintenance tasks. Taking into account the functioning specificity and conditions of technical

network systems, it was assumed, that the development of the assessment model would be based on four categories of maintenance works, including: inspections, maintenances, repairs, overhauls, and three key features: costs, time, quantity of the maintenance tasks.

Based on the assumptions presented, there was developed the quantitative model of the assessment of the exploitation policy, based on data of three technical network systems: the water supply system, the sewage system and the heating system. The structure of the data sets describing the exploitation policy of the analyzed technical network systems, in the single cycle are summarized in table 13.2 and illustrated in Fig. 13.1.

Table 13.2 The structure of the data sets describing the exploitation policy of the analyzed technical network systems

Water supply system						
	Costs [PLN]		*Time [hours]*		*Quantity*	
Inspections	151 819,73	14,42%	38642	47,56%	6328	65,25%
Maintenances	146 773,18	13,94%	22965	28,26%	1544	15,92%
Repairs	192 134,67	18,25%	8741	10,76%	530	5,47%
Overhauls	561 928,82	53,38%	10908	13,42%	1296	13,36%
Amount	**1 052 656,40**	**100,00%**	**81256**	**100,00%**	**9698**	**100,00%**
Sewage system						
Inspections	140 123,26	30,35%	80072	44,06%	16494	57,10%
Maintenances	32 716,52	7,09%	22290	12,27%	2519	8,72%
Repairs	188 450,62	40,81%	48235	26,54%	8851	30,64%
Overhauls	100 460,54	21,76%	31129	17,13%	1022	3,54%
Amount	**461 748,03**	**100,00%**	**181726**	**100,00%**	**28886**	**100,00%**
Heating system						
Inspections	99 150,21	4,36%	9915	16,28%	276	29,71%
Maintenances	286 575,32	12,59%	19105	31,37%	253	27,23%
Repairs	853 667,52	37,51%	17073	28,04%	154	16,58%
Overhauls	1 036 363,35	45,54%	14805	24,31%	246	26,48%
Amount	**2 275 755,00**	**100,00%**	**60898**	**100,00%**	**929**	**100,00%**

Source: own study

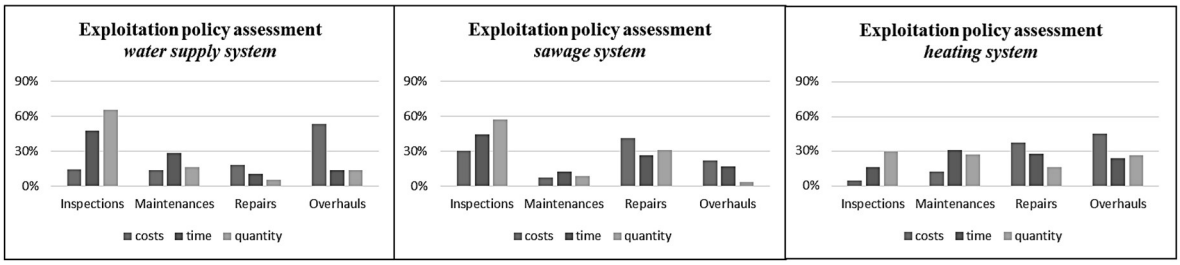

Fig. 13.1 Graphical image of the exploitation policy assessment

Source: own study

13.4 INTERPRETATION OF THE RESULTS

The analysis of the features values of the exploitation policy assessment model of the examined technical network systems showed a large diversity of the structure of undertaken and performed maintenance works (Fig. 13.1).

The exploitation policy, carried out in relation to the analyzed water supply system, is characterized by a large number and time-consuming diagnostic works (inspections), with their negligible economic value. It is also noted significant position of the overhauls – the high cost of these works, with insignificant time value and works quantity.

According to the above interpretation, it should be stated, that the exploitation policy for the analyzed water supply system is preventive of the diagnostic type, with using, in the decision-making process, corrective works conditioned by the criterion assessment of the technical condition. This is indicated by a significant quantity and time value of the inspections, at a low cost of these works.

The exploitation policy, carried out in relation to the analyzed sewage system, is characterized by quite clear and comparable meaning of two categories of maintenance works, ie. the inspections and repairs, which, in a methodological sense, are counterproductive. In particular, the assumption of regular and proper condition control, should lead to a significant limitation of unintended events and the need for costly and time-consuming repairs. The author suggests adopting the above maintenance system as a transitional situation, with great need and possibility of rationalization.

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

13.5 SUMMARY

Development of the assessment model of the exploitation policy allows you to analyze functioning of the maintenance organizations of the examined network enterprises. Four concepts are possible and practically justified in this area:

- simple analysis of the exploitation policy of the technical network system,
- mutual comparative analysis of the exploitation policy, of the maintenance organizations with similar business specificity (eg. a comparison of the two organizations maintain separate networks),
- time comparative analysis of the exploitation policy, of the maintenance organization, carried out in relation to the different periods,
- simulation analysis of the exploitation policy, of the maintenance organization, based on controlled change of the selected features.

With the above mentioned concepts, the first and the second are static, relating to a specific moment in time. While the two other concepts, due to the high variability of the time, can be used to assess the functioning of the maintenance organization under conditions of dynamic changes in the environment, both in the relation of past features – current features, as well as in relation to the planned, considered or simulated condition and specificity of the exploitation policy.

REFERENCES

1. A. Adamkiewicz, A. Burnos, *The maintenance of the ship turbines with the application of the key performance indicators*, Journal of POLISH CIMAC Diagnosis, reliability and safety, Vol. 5 No. 2, 2010, pp. 7-16.
2. A. Kelly, *Strategic Maintenance Planning*, Oxford (UK): Butterworth-Heinemann, 2006.
3. J. Levitt, *The Handbook of Maintenance Management*, New York: Industrial Press Inc.: 2009.
4. A. Loska, *Exploitation assessment of selected technical objects using taxonomic methods*, Eksploatacja i Niezawodnosc – Maintenance and Reliability, 15(1), 2013, pp. 1-8.
5. W.B. Niebel, *Engineering Maintenance Management*. New York: Marcel Dekker Inc., 1994.
6. R.W. Peters, *Maintenance Benchmarking and Best Practices: A Profit – and Customer – Centered Approach*, New York: McGraw-Hill, 2006.
7. *Obsługa - Kluczowe wskaźniki efektywności*, PN-EN 15341:2007.
8. T. Suzuki, *TPM in Process Industries*, Portland (Oregon): Productivity Press, 1994.

Date of submission of the article to the Editor: 04.2017
Date of acceptance of the article by the Editor: 05.2017

dr inż. Andrzej Loska
Silesian University of Technology
Faculty of Organization and Management
Institute of Production Engineering
ul. Roosevelta 26-28, 41-800 Zabrze, Poland
tel.: +4832 277 73 63, e-mail: Andrzej.Loska@polsl.pl

ANALYTICAL MODEL OF THE EXPLOITATION POLICY ASSESSMENT OF TECHNICAL NETWORK SYSTEMS - CASE STUDY

Abstract: *The article take issues of the exploitation policy assessment of technical systems. After the discussion of the mathematical models possible for use in the assessment of the functioning of technical systems in enterprises, an analytical concept based on the resultant of the three features is presented: time, costs i quantity of maintenance tasks, referred to the four work categories. The proposed concept was verified for selected technical network systems. The last aspect of the article is the analysis and interpretation of the results obtained in the context of the exploitation policy assessment.*

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

ANALITYCZNY MODEL OCENY POLITYKI EKSPLOATACYJNEJ SIECIOWYCH SYSTEMÓW TECHNICZNYCH - STUDIUM PRZYPADKU

Streszczenie: *Artykuł podejmuje problematykę oceny polityki eksploatacyjnej systemów technicznych. Po przeprowadzonej dyskusji nad modelami matematycznymi możliwymi do zastosowania w ocenie funkcjonowania służb technicznych przedsiębiorstw, przedstawiono koncepcję analityczną opartą na wypadkowej trzech wielkości: czasu, kosztów i liczby prac obsługowo-naprawczych, odniesionej do czterech kategorii prac. Zaproponowaną koncepcję poddano weryfikacji dla wybranych sieciowych systemów technicznych. Ostatnim aspektem podejmowanym w artykule jest analiza i interpretacja uzyskanych wyników w kontekście oceny polityki eksploatacyjnej.*

Słowa kluczowe: *polityka eksploatacyjna, sieciowe systemy techniczne, efektywność eksploatacyjna, zarządzanie utrzymaniem ruchu*