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EXPLOITATION ASSESSMENT OF SELECTED TECHNICAL OBJECTS USING TAXONOMIC METHODS

EKSPLOATACYJNA OCENA WYBRANYCH OBIEKTÓW TECHNICZNYCH Z ZASTOSOWANIEM METOD TAKSONOMICZNYCH*

The article is an attempt to answer the formulated problems in industrial enterprises problems on practical aspects of use of specific measures to assess exploit of technical facilities. In this regard, bibliography study has been conducted, including an overview of opportunities to develop the values of selected exploitation characteristics, as well as industrial research as a need analysis of technical departments in the assessment of their performance. As a result of these studies and their conclusions method of preliminary mutual exploitation evaluation has been developed, based on the values of standardized and aggregated ranks of technical objects, in the context of exploitation measurements calculated. This method, as well as an example of its use, relating to a selected network technical system, are the subject of further sections of this article.

***Keywords**: exploitation assessment, numerical taxonomy, rank.*

Artykuł jest próbą odpowiedzi na formułowane w przedsiębiorstwach przemysłowych problemy dotyczące praktycznych aspektów wykorzystania określonych miar do oceny eksploatowania obiektów technicznych. W tym zakresie, przeprowadzono badania literaturowe obejmujące przegląd możliwości kształtowania wartości wybranych cech eksploatacyjnych, a także badania przemysłowe dotyczące analizy potrzeb służb technicznych przedsiębiorstw w zakresie oceny ich funkcjonowania. Wynikiem przeprowadzonych badań i sformułowanych w tym zakresie wniosków, została opracowana metoda wstępnej wzajemnej oceny eksploatacyjnej w oparciu o wartości normowanych i zagregowanych rang obiektów technicznych w świetle wyznaczanych miar eksploatacyjnych. Metoda ta, jak również przykład jej zastosowania, odnoszący się do wybranego sieciowego systemu technicznego są przedmiotem dalszej treści tego artykułu.

***Słowa kluczowe**: ocena eksploatacyjna, taksonomia numeryczna, rangowanie.*

Introduction

Reliable valuation of maintenance tasks is one of key criteria of the proper functioning of the maintenance departments in any industrial enterprise. It means the necessity of determining the values of selected features, and consequently the possibility of shaping the decision-making processes relating to implementation of maintenance work.

In industrial practice, it is used exploitation measures (indicators) in a wide variety. Their values refer to the individual technical objects, as well as to maintenance organization's activities. This variety can significantly influence the choice of particular set of features, in specific individual organizational and technical circumstances: in a positive way – by a clear reflection of assessment of exploitation policies, in a negative way – by too much emphasizing less important trends, and active "shaping" value of certain measures.

From a mathematical point of view, the exploitation problems of identified and formulated in industrial enterprises should be considered in the category of complex phenomena and processes, that require implementation of the works of technical, organizational and economic nature in time and spatial environment. This complexity is characterized by many features that translate into measures with different titers and scale rows, which means that they are mutually incomparable. Such comparability seems to be possible after reducing key measures to the so-called. "common denominator" based on standardization methods, and then their synthesis with the use of aggregation methods.

This article is an attempt to solve such the problem through the elaboration of rank method of technical objects in terms of the exploitation features. The resulting exploitation assessing method is one of the key elements of research, conducted by the author of this article, in the use of scenario techniques in modelling exploitation events and processes.

(*) Tekst artykułu w polskiej wersji językowej dostępny w elektronicznym wydaniu kwartalnika na stronie ***www.ein.org.pl***

2. Classification and characteristics of selected exploitation assessment models

There are several mathematical models underlying the quantitative assessment of exploit of technical objects and functioning of the maintenance organization. The individual sets of measurements are the subject of many publications, in the form:

- separate bibliography items, mostly in the form of sheet workbooks, containing an ordered list and description of specific measures, including in [26, 27, 32, 34, 36],
- parts of methods and techniques of maintenance management, as addition to the description of maintenance strategies and maintenance management systems, including in [2, 4, 9, 12, 14, 17, 22, 23, 33],
- parts of maintenance strategies and systems applications into certain industrial enterprises, including in [7, 11, 18],
- modes of interpretation (usually mathematical) and attempts to apply selected exploitation measures, including in [1, 3, 15, 31].

From a practical industrial point of view, developments and studies assigned to groups third and fourth are becoming especially importance. These include the concepts and practical solutions for the use of well-known mathematical models in practical applications. This is a direct and most important subject of the needs and expectations the majority of industrial centres.

Based on the diagnosis results presented in [20] review and analysis has led to the distinguish of these models which are most important, both in theoretical aspects – bibliography, and practical - the industrial. There are three general models in thisarea:

a) reliability model [5, 10, 12, 23, 28],
b) Overall Equipment Effectiveness (OEE) model [22, 33, 34],
c) Key Performance Indicators model (KPI) [27, 32].

2.1. The computable reliability model

The reliability model allows us to determine exploitation measures in statistical approach. In industrial practice, it is the result of these maintenance strategies, in which decisions concerning the possibility of use technical objects and the dates and scopes of maintenance tasks are directly related to the time analysis of the statistical sight of technical objects functioning, described by group models.Reliability model is reflected by the measures, that relate to:

a) exploitation objects in terms of technical – measures that are the result of identification of the technical condition (in the form of probability) referenced to particular classes (for example, the reliability function in terms of the exponential distribution [10, 28], failure intensity [5], or technical availability ratio [12]),
b) exploitation objects in terms of both – organizational and technical – measures which result from the identification of the technical condition, as well as organizational and economic activities of exploitation departments (eg. defined by [23] MTBF, MTTR or MFOT).

2.2. The computable Overall Equipment Effectiveness model (OEE)

The Overall Equipment Effectiveness model is the most important component of quantitative evaluation of TPM. Due to the high flexibility, this model is also used in these companies that have not implemented this strategy. It expresses the overall efficiency of maintenance by three main factors(Tab. 1).

It should be noted that due to the method of OEE calculating (product of the sub-indices), it is important not so much the absolute value of the OEE, but the conclusions resulting from the way of obtaining it.Mathematical interpretation of the OEE should have a geometric character. In particular, OEE can be presented in three dimensions, where the axes represent individual sub-indices. In this approach, presenting OEE as a vector, you can make conclusions and decisions arising from this model, which should relate to:

- absolute valueof OEE,
- influence of individual factors on the value of OEE,
- direction and value of changeof OEE.

2.3. The computable Key Performance Indicators model (KPI)

The Key Performance Indicators model includes a set of measures of productivity and efficiency. These measures allow for a comprehensive assessment of the implementation of the maintenance organization's objectives, meaning that in practice they must be closely related to the maintenance strategy of the company.From the examinations made, we can conclude that there are many varieties of KPI model, which are related to specific application. Therefore, for several years there has been a need to harmonize both the measures included in this model, as well as the interpretation of particular indicators and the general model of KPI. On this basis standard EN 15341:2007 (Maintenance – Maintenance Key Performance Indicators) has been developed, which contains a unified set of measures as part of the KPI model [27].

The standard contains 72 indicators, along with a detailed interpretation of the constituent components. These indicators may be subject to interpretation and comparison with the values obtained in other companies of the industry. Selected examples of indicators are:

E1 – total relative maintenance cost for technical object:

$$E1 = \frac{total\ maintenance\ cost}{asset\ replacement\ value} \tag{4}$$

T7 – availability of objects for preventive maintenance:

$$T7 = \frac{total\ operating\ time}{total\ operating\ time + downtime\ related\ to\ planned\ and\ scheduled\ maintenance} \tag{5}$$

Table 1. Indicators of Overall Equipment Effectiveness OEE [22]

Availability	Performance efficiency	Rate of quality products
$D = \frac{t_d - t_p}{t_d}$ (1)	$E = \frac{t_c \cdot n}{t_o}$ (2)	$J = \frac{n-d}{n}$ (3)
t_d - loading time t_p - downtime	t_c - theoretical cycle time n - processed amount t_o - operatingtime	n - processed amount d - defect amount
$OEE = D \cdot E \cdot J$		

3. The concept of exploitation assessment of technical objects

For complex organizational and technical conditions of exploitation systems and not very detailed explicit expectations of potential managers, variety of measures, can lead to:

- ambiguity of measures interpretation of the impact of individual factors on the exploitation efficiency of the objects understood in a broad sense,
- substantively unreasonable emphasize of selected aspects in contrast to other in the context of maintenance policy of the company.

In other words, for each maintenance indicator, there must be reasonably necessary to its determination, and also position and weight of each of the measures under consideration in terms of technical, organizational or economic are important.

Described factors generate the need to develop, verify and practical application of such assessment models, which include the necessary but also sufficient number and range of measures, in specific organizational and technical conditions Their importance shall be more appropriate for the purpose of company, and less to the particular interests of individual persons or organizational units.

The conclusions resulting from the bibliographic analysis and industrial studies are the starting point to develop a method of exploitation assessment based on recognized and defined theoretical (model) conditions and limitations as well as observations and practical experience (industrial).

Proposed by the author method uses elements of taxonomic methods that are known and applied in the field of socio-economic sciences [8, 16, 25]. In this case they are helpful in selecting, organizing, and grouping of the analyzed phenomena and events in the fields: space, essential and timing. Effect of these is transformation of diagnostic variables describing the various parts of the analyzed phenomena in a dispersed way in a synthetic variable (aggregated), which is kind of resultant considered events and exploitation processes. In this view, the construction of the exploitation assessment procedure consists of three key aspects:

- selection and hierarchization of diagnostic features (diagnostic feature is here assumed broader than the typical terms of exploitation and reliability, so by [25] it is the potential and the initial feature that allows to explain a particular phenomenon),
- standardization of dissimilar diagnostic variables, in order to achieve uniform titers,
- aggregation of standardized variables, to output a synthetic variable (aggregated) for the determining the values of rank of comparable technical objects.

Selection allows you to isolate those features describing the technical objects and exploitation processes that can have a significant role in the assessment process. The second criterion for features selection is the availability of measurement. In the aspect of practical use of measures to evaluate exploitation of technical object and exploitation processes, there can be distinguished a set of several key features, that would be the basis for the selection. Such features, that have been characterized in detail [12, 19] and systematized in [38], should include: condition, reliability, quality, functionality, efficiency, maintainability diagnosis. These features should be rather treated as a groups, than a single elements. Within each group, there can be localized measures (indicators) describing and evaluating some exploitation aspects of technical objects as well as maintenance departments functioning.

Hierarchization is a part of the arrangement of selected features in order to determine explicit diagnostic variables and to specify their nature. In the exploitation area, nature of the diagnostic variables allows you to organize the attributes into three groups (by [8]):

- stimulants, for which high values of characteristics are desired (eg. mean time between failures – MTBF),
- destimulants, for which low values of characteristics are desired (eg. cost of emergency work),
- nominants, for which "normal" values of characteristics are desired (eg. costs of corrective work as a result of preventive tasks).

Action in relation to the harmonization of the nature of the variables should be carried out according to the postulate of uniform preference, which is to extract and assign attributes to one of the above categories, choice of the trend and to make so called the inverse transformation of those features which have been classified into groups with opposing trends. In other words, destimulants can be converted to stimulants based on established limits (for example, the theoretical values or minimum and maximum values collected in the entire history of measurements made). In relation to nominant, we can assume that any deviation from the values of normal level is an unfavuorable phenomenon. Therefore, such a transformation is necessary to establish their level of "normal" and then involves two steps: transformations in destymulants, which are features of absolute deviation from the level of "normal" and then in the stimulants.

The next step, after the selection and ordering of diagnostic variables, is the normalization of features, that results from the dissimilar values of the variables. This process should proceed according to the additivity postulate [16], which means that it is necessary to transform the original diagnostic variables to get a value-free titers and standardized in term of magnitude order. According to [16] such a process can be carried by the following general relation:

$$x_i' = \left(\frac{x_i - A}{B} \right)^p \quad (i = 1, \ldots, n) \tag{6}$$

where: x'_i – output normalized value of the i-th realization of the variable,
x_i – unnormalized value of the i-th realization of the variable,
n – number of observations,
A, B, p – parameters with values depended on the method of normalization.

Adequate normalization methods, including standardization, unitarization or quotient transformation with a reference value, were discussed in detail in the, including [8, 16].

The last step is the aggregation. This is process, which leads directly to obtain a synthetic variable. In the approach considered here, it is rank describing the value of the individual technical objects, in terms of analyzed events and exploitation processes. Aggregation is usually carried out on the basis of the so-called additive formulas [16]. They represent different forms of sum of the products of standardized features and corresponding weights. Typical procedure of aggregation consist of looking for the numerical values of following vector of the aggregate:

$$[Q_i] = \begin{bmatrix} Q_1 \\ Q_2 \\ \vdots \\ Q_n \\ \end{bmatrix} i = (1, 2, \ldots, n) \tag{7}$$

where: Q_i – aggregate value of the function determined for the i-th object.

A typical form of aggregation is the correlation function [37]:

$$Q_i = \sum_{j=1}^{s} z_{ij}\omega_j i = (1,2,\ldots,n), \omega_j \epsilon R_+ \quad (8)$$

where: z_{ij} – value of the i-th assessment of the j-th variant,
ω_j – weight value.

Another example of the aggregation function is its weighted value referenced to the arithmetic mean [24]:

$$Q_i = \frac{\sum_{j=1}^{s} z_{ij}\omega_j}{\sum_{j=1}^{s}\omega_j} i = (1,2,\ldots,n), \omega_j \epsilon R_+ \quad (9)$$

The equations (8) and (9) show, that important role in the aggregation process fulfills the weights system, which can be based on expert opinion – on the one hand, as well as statistical procedures with the use of collected information on the variables – on the other hand.

4. The rank method of technical objects in view of their exploitation characteristics

The methodological and conceptual assumptions about the possibilities and needs of the exploitation assessment became the basis for a rank process of selected technical objects. The purpose of rank process is exploitation ordering of equivalent technical objects based on the history of events and processes with all their circumstances. There have been specified following initial conditions:

- the basis of rank method includes broad set of measures,as a determinant of a comprehensive exploitation assessment of the technical objects and maintenance organization functioning,
- proposed rank method is based on general assumptions of taxonomic methods (described earlier),
- all weights assigned to each measurement and decision-making levels and the way of measures organizing in the assessment table, have been defined in a subjective manner, based on expertise and consultation,
- rank method subjects to peer evaluation (peer comparison), equivalent technical objects (in terms of maintenance management) for analysis therefore, itself rank value is not important but it is important its relation to the ranks of other objects.

The first step is selection of measures (indicators) representing a quantitative basis for assessing the exploitation technical objects. Based on recognition made, it should be noted clearly, that a certain set of measures is individual in each specific case, depending on the detailed technical and organizational conditions of the company and its maintenance department. Independently of selection of specific measures, classification is a key aspect of the method. At this point, the measures arrangement was made in three main categories:

- economic measures (indicators), which express the cost value of the selected exploitation aspects,
- technical measures (indicators), which express the time value of the selected exploitation aspects,
- organizational measures (indicators), which express the non-technical (around of exploitation) value of the selected exploitation aspects.

The collection of sample measures, that have been selected based on [27] and arranged according to the above system, is shown in Tab. 2.

The selected measures of performance describe in a quantitative manner the various aspects, and thus, they are expressed in different units, mutually not comparable. According to the basic assumptions of the method, it is equivalence of all the necessary measures, in other words, these measures must be reduced to the same rating scale. In addition, we are dealing here with both stimulants and destimulants. It is therefore proposed to perform a normalization process, including unification of values, taking into account:

- express the value of assessment in relative terms (related to the maximum and minimum measure values obtained in the entire history of measuring in the organizational and technical system),
- express the value of assessmentin the range <0 , 10>, which will allow to reduce individual measures from the appointed form (eg. zł/m^3) to the not appointed form in one range (od 0 do 10), thus possible to compare,
- establish a uniform trend of the indicators (according to the author, a better solution is a positive trend - stimulants - greater value is better).

Based on the above criteria, you can determine the value of assessment for exploitation measures:

1. For the measures of a positive trend – stimulants:

Table 2. Sample exploitation measures (own ellaboratoin based on [27])

Economic measures	Technical measures	Organizational measures
The measure (indicator) of operation costs related to the production quantity	The measure (indicator) of the breakdown actions time	The measure (indicator) of maintenance employees participation rate in a total amount of company's own staff
The measure (indicator) of operation costs and lack of service and production quantity	The measure (indicator) of the corrective actions time	The measure (indicator) of maintenance indirect employees participation rate in the total amount of maintenance employees
The measure (indicator) of personnel costs related to the total maintenance costs	The measure (indicator) of the preventive actions time	Potential ratio of staff in the planning process
The measure (indicator) of material resources use cost	The measure (indicator) of the diagnosis actions time	The measure (indicator) of number of maintenance activities with accidents
The measure (indicator) of specialized tools and equipment use cost	The measure (indicator) of mean time between failures (MTBF)	The measure (indicator) of number of maintenance activities with maintenance hazards
The measure (indicator) of sharing corrective tasks costs in the total maintenance costs	The measure (indicator) of mean time to repear (MTTR)	The measure (indicator) of number of maintenance activities with environmental events
The measure (indicator) of sharing preventive tasks costs in the total maintenance costs	The measure (indicator) of mean force outage time (MFOT)	The measure (indicator) of number of maintenance activities with environmental hazards
The measure (indicator) of sharing diagnosis tasks costs in the total maintenance costs	The measure (indicator) of the technical object availability	Potential ratio of staff in the preventive tasks
The measure (indicator) of sharing breakdown tasks costs in the total maintenance costs	The measure (indicator) of the maintenance tasks effectiveness	Potential ratio of staff in the corrective tasks
	The measure (indicator) of the effectiveness of maintenance tasks planning	Potential ratio of staff in the diagnosis tasks
		Potential ratio of staff in the breakdown tasks
		The measure (indicator) of maintenance employees overtime

$$OC_{is} = \frac{10 \cdot M_i}{M_{i_{\max}} - M_{i_{\min}}} \tag{10}$$

where: OC_i – selected (i-th) exploitation assessment,
M_i – selected (i-th) exploitation measure,
M_{imax} – maximum value of exploitation measure in the whole history measuring in the given organizational and technical system,
M_{imin} – minimum value of exploitation measure in the whole history measuring in the given organizational and technical system.

It is assumed that for all measures considered here, the minimum value $M_{imin} = 0$, so:

$$OC_{is} = \frac{10 \cdot M_i}{M_{i_{\max}}} \tag{11}$$

2. For the measures of a negative trend - stimulants- destimulants:

$$OC_{id} = 10 - \frac{10 \cdot M_i}{M_{i_{\max}} - M_{i_{\min}}} \tag{12}$$

for $M_{imin} = 0$:

$$OC_{id} = 10 - \frac{10 \cdot M_i}{M_{i_{\max}}} \tag{13}$$

Determined values can be ordered in the table of exploitation measures (Tab. 3).

Table 3. Exploitation assessment table

	Economic measures weight k_1	Technical measures weight k_2	Organizational measures weight k_3
Level 1 weight p_1	a_{11}	a_{12}	a_{13}
	$OC_{E1},...,OC_{Em}$ (sum of the weights is 1)	$OC_{T1},...,OC_{Tm}$ (sum of the weights is 1)	$OC_{O1},...,OC_{Om}$ (sum of the weights is 1)
Level 2 weight p_2	a_{21}	a_{22}	a_{23}
	$OC_{Em+1},...,OC_{En}$ (sum of the weights is 1)	$OC_{Tm+1},...,OC_{Tn}$ (sum of the weights is 1)	$OC_{Om+1},...,OC_{On}$ (sum of the weights is 1)
Level 3 weight p_3	a_{31}	a_{32}	a_{33}
	$OC_{En+1},...,OC_{Ep}$ (sum of the weights is 1)	$OC_{Tn+1},...,OC_{Tp}$ (sum of the weights is 1)	$OC_{On+1},...,OC_{Op}$ (sum of the weights is 1)

where:
OC_{Ei} - exploitation assessment of an economic type,
OC_{Ti} - exploitation assessment of an technicaltype,
OC_{Oi} - exploitation assessment of an organizational type

This table includes:
- types of exploitation assessments (economic, technical, organizational), the sum of the weights must be equal to one($k_1 + k_2 + k_3 = 1$),
- decision-making levels, the weights have the following values: $p_1 = 4$, $p_2 = 2$, $p_3 = 1$.

From the data included in the assessment table (Tab. 3), it should be determined:
1. Exploitation assessment matrix:

$$W = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \tag{14}$$

where:

$$a_{ij} = \sum_{i=1}^{N} OC_{ij} \cdot g_i \tag{15}$$

$$\sum_{i=1}^{N} g_i = 1 \tag{16}$$

a_{ij} – standarized weighted sum of exploitation assessment calculated for the object,
OC_{ij} – exploitation assessment,
g_i – weight value referred to the single assessment.

2. Vector of tasks category:

$$K = \begin{bmatrix} k_1 \\ k_2 \\ k_3 \end{bmatrix} \tag{17}$$

where:
K – the set of weight related to the category (economic, technical, organizational),
k_i – weight of the i-th category.

Vector of category enables you to define weights for certain types of assessments. This allows the proper definition of the importance of company maintenance. For example:
- high value of economic category weight at lower value of technical and organizational category weight may point to carry out maintenance activities with particular emphasis on the resulting cost,
- high value of technical category weight at lower value of economic and organizational category weight means the implementation of maintenance activities, reliability and efficiency improvement with less emphasis on cost and number of man hours.

The values of the category vector can be shaped in any way, with the assumption that:

$$\sum_{i=1}^{N} k_i = 1 \tag{18}$$

3. Vector of decision-making levels:

$$P = \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix} \tag{19}$$

where:
p_i – weight of the i-th level of the organizing company:
p_1 – weight of company level,
p_2 – weight of technical departmentlevel,
p_3 - weight of maintenance department level.

Vector of decision-making levels allows you to emphasize these assessments that in the decision making process have a specific meaning in relation to company maintenance policy This role results main-

ly from maintenance strategy as well as organizational and decision-making structures, that are built on the basis. In particular, the vector includes:

- weight of company level (p_1) - taking into account the strategic decisions and the associated assessment, taking into account the strategic decisions and the associated assessment directly related to operational policy and the functioning of the maintenance department as a whole,
- weight of technical department level - taking into accountdecisions and the related assessment of the planning and implementation of maintenance activities,
- weight of maintenance department level - taking into account operating decisions and the related assessment of the specific ways of implementing of maintenance tasks.

The hierarchical nature of the levels of decision-making and responsibility for specific maintenance tasks allow to determine the value of vector of decision-making levels, applying the principle that the weight of the higher level is a multiple of the weight directly to a lower level:

$p_3 = 1$,
$p_2 = 2$,
$p_1 = 4$.

The values of the vector of decision-making levels are contractual in nature and can be differently shaped in relation to another company.

Based on pre-defined and determined matrices and vectors, rank of the object is calculated, as a result of aggregation:

$$R = (W \cdot K) \cdot P^T \tag{20}$$

In particular:

$$R = \left(\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \cdot \begin{bmatrix} k_1 \\ k_2 \\ k_3 \end{bmatrix} \right) \cdot \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix}^T \tag{21}$$

Table 4. Table of exploitation assessment for an example network technical system

	Economic measures weight $k_1 = 0,5$		Technical measures weight $k_2 = 0,3$		Organizational measures weight $k_3 = 0,2$	
Level 1 weight $p_1 = 4$	a_{11}		a_{12}		a_{13}	
	Assessment	Weight (g_i)	Assessment	Weight (g_i)	Assessment	Weight (g_i)
	OC_{E1} OC_{E2} OC_{E3} OC_{E14}	0,35 0,25 0,2 0,2	OC_{T9} OC_{T10} OC_{T14} OC_{T15} OC_{T16} OC_{T17}	0,2 0,15 0,2 0,25 0,1 0,1	OC_{O1} OC_{O2} OC_{O3}	0,4 0,35 0,25
Level 2 weight $p_2 = 2$	a_{21}		a_{22}		a_{23}	
	Assessment	Weight (g_i)	Assessment	Weight (g_i)	Assessment	Weight (g_i)
	OC_{E4} OC_{E5} OC_{E6} OC_{E7} OC_{E8}	0,35 0,25 0,2 0,1 0,1	OC_{T11} OC_{T12} OC_{T13}	0,45 0,25 0,3	OC_{O4} OC_{O9}	0,6 0,4
Level 3 weight $p_3 = 1$	a_{31}		a_{32}		a_{33}	
	Assessment	Weight (g_i)	Assessment	Weight (g_i)	Assessment	Weight (g_i)
	OC_{E9} OC_{E10} OC_{E11} OC_{E12} OC_{E13}	0,3 0,25 0,2 0,15 0,1	OC_{T3} OC_{T14} OC_{T5} OC_{T6} OC_{T7} OC_{T8}	0,25 0,2 0,2 0,15 0,15 0,05	OC_{O5} OC_{O6} OC_{O7} OC_{O8}	0,35 0,25 0,15 0,25

$$R = \begin{bmatrix} a_{11} \cdot k_1 + a_{12} \cdot k_2 + a_{13} \cdot k_3 \\ a_{21} \cdot k_1 + a_{22} \cdot k_2 + a_{23} \cdot k_3 \\ a_{31} \cdot k_1 + a_{32} \cdot k_2 + a_{33} \cdot k_3 \end{bmatrix} \cdot \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix}^T \tag{22}$$

$$R = \left[(a_{11} \cdot k_1 + a_{12} \cdot k_2 + a_{13} \cdot k_3) \cdot p_1 + (a_{21} \cdot k_1 + a_{22} \cdot k_2 + a_{23} \cdot k_3) \cdot p_2 + (a_{31} \cdot k_1 + a_{32} \cdot k_2 + a_{33} \cdot k_3) \cdot p_3 \right] \tag{23}$$

Determined rank is the value of the object in relation to other ranked objects.

5. Example of ranks calculating for objects of the selected network technical system

Presented rank method can be applied in many cases of technical systems exploing under the following terms:

- it is necessary to extract the equivalent of comparable objects or parts of technical systems,
- it is necessary to prepare complete data resources on all exploitation events that occurred within the object.

Taking into account above guidelines, it is assumed that the subject of example is a water supply system - typical network technical system. The system functions as a collective water supply which consists of the recognition, treatment and water supply to its customers. The exploitation specificity of water supply system is determined by three aspects [13]:

- vast majority of the water supply system components operate in difficult to access location (such as underground), which makes it difficult or impossible to carry out such preventive work, which are typical for manufacturing companies (eg, review),
- proper functioning of the water supply system is required to ensure continuity and quality of facilities within an extensive technical infrastructure geographically dispersed over a large area,
- specificity of construction and location of the water supply system causes, that The largestsharehavethe works carried outwithin the breakdown maintenance strategy, and the lowest numberof objects issupportedunder the predictive maintenance strategy.

For this example it was assumed that objects, that are the basis for decision making and subject of analysis, are fragments of pipeline assigned to particular streets, assigned to particular streets, with all the technical components. An ordered set of weights and assessments are shown in Tab. 4.

OC_{ij} values have been designated on the basis of:

- mathematical formulas of indicators presented in Tab. 2. and included in [27],
- formulas (10) – (13).

Part of a set measure values and the corresponding assessments for the selected of technical objects (streets) are shown Tab. 5. The table includes the results of the analysis of six of the nearly one hundred objects, which allows to show the idea and possibility of practical realization of the proposed method, as well as a practical way to restrict the presentation area.

As a result of the calculation, according to equations (15) – (16), matrix values have been designated for individual objects (Tab. 6).

Next, rank vector of objects (streets) was calculated, based on the (20) – (23).

Object (street)	R
Object 1	152,8236
Object 2	159,8538
Object 3	162,3891
Object 4	163,4277
Object 5	171,5911
Object 6	177,6439

Table 5. Part of a set measure values and the corresponding assessments for the selected of technical objects (streets)

Object (street)	E_1	OC_{E1}	T_{11}	OC_{T11}	O_6	OC_{O6}
Object 1	0,3493	9,7049	0,0004	0,2278	0,0251	9,9094
Object 2	3,7983	6,7916	0,0006	0,2941	0,0709	9,7439
Object 3	5,1721	5,6312	0,0006	0,3448	0,1270	9,5411
Object 4	0,0335	9,9716	0,0004	10,000	0,0098	9,9646
Object 5	0,2591	9,7811	0,0004	5,0000	0,1807	9,3468
Object 6	0,098	9,9171	0,0002	0,2564	0,0521	9,9812

Table 6. The set of matrix elements of the exploitation assessments W for selected technical objects

Object (street)	a11	a12	a13	a21	a22	a23	a31	a32	a33
Object 1	7,5390	7,0727	10	8,9896	5,2279	9,3259	9,1634	6,9476	9,9463
Object 2	5,8716	7,0509	10	9,1802	4,9882	9,5678	9,1657	5,5745	10,000
Object 3	5,3614	5,6458	10	8,6021	5,1581	9,7208	7,1919	5,0159	9,7836
Object 4	7,4951	8,0000	10	6,0269	9,6029	8,3353	9,9798	6,1449	9,5250
Object 5	7,9525	7,5000	10	7,3498	7,3529	9,7100	9,9798	7,4237	9,6677
Object 6	7,3723	7,6213	10	9,1224	3,8801	8,6855	9,8824	7,4913	9,9073

6. Conclusions

According to the author, the article is part of the discussion on ways and effects of the operational assessment, on-going among employees of the maintenance departments of industrial companies. Presented here, rank method of technical objects can be an attempt to answer to the constantly present question in this area:

- which measures are most adequate in the considered organizational and technical system?
- what would be the importance (weight) of a particular measure in the considered organizational and technical system?
- which criteria (measures) should be the basis for comparing objects and/or maintenance departments?

It should be noted that the prepared method is a developmental. At the current stage industrial research is being conducted. They depend on verifying the correctness and effectiveness of the rank method based on data from the real working environment - the activities of maintenance departments – water and sewage, production companies. Verification will allow to make parameterization and positioning of the rank method, which relates to certain ambiguities of the method and its weak points, which concern:

- measures selection,
- ways of determining the weights,
- full use of the objects rank in company strategic planning.

In terms of optimizing of weights and measures selection, author is going to use the methods from the area of Analytic Network Process, whose precursor is T. Saaty [29, 30] and which are developed in different areas by many other authors, such as [6, 35].

The developed rank method is a part of research conducted by the author at the Institute of Production Engineering of the Silesian University of Technology. These studies concern the ways of modelling events and exploitation processes using the scenario methods.

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