

**METHODS AND TECHNIQUES OF PREDICTION OF KEY PERFORMANCE INDICATORS
FOR IMPLEMENTATION OF CHANGES IN MAINTENANCE ORGANISATION**

Andrzej WIECZOREK
Silesian University of Technology

Abstract:

The article presents the concept of how to assess the future state of the organization in the area of using and maintenance of technical means, basing on the combination of "classic" prognostic model with models - components of the selected computer tools. Presentation of this concept was preceded by the definition and characteristics of maintenance key performance indicators. It also presents a requirements and method of KPIs selection.

Key words: maintenance management, reliability, prediction, computer support, GIS, CMMS, EAM, ERP, KPI

INTRODUCTION

Assessment of current state and the implementation of changes in the organization in the area of using and maintenance of technical means as a consequence of this assessment needs of the analyzes, based on the accepted measures. Examples of such measures may be maintenance key performance indicators. They allow to assess using and maintenance processes and systems of economic, technical and organizational point of view. The values of these indicators are usually the result of diagnosis of the current state of the organization, carried out using actual using and maintenance data. On their basis, in many cases there is a need for the assessment of future state of organization of the selected term, or determine what will happen in the organization as a result of changes in its functioning. In such cases it is necessary to propose methods of forecasting and simulation (such as: what – if ?). Their use requires association of appropriate methods of simulation and forecasting with techniques of data collection and processing and development of appropriate methods of interpreting the obtained results of calculations. Using and maintenance systems, which are the subject of this assessment are the components of the organization and can be assigned to one location or may be geographically dispersed (have many locations). It is therefore necessary to use methods that take into account not only the time domain, but also the aspect of space to making a decision to implement changes in the organization.

Therefore, in article presents the concept of how to assess the future state of the organization in the area of using and maintenance. It uses a combination of "classic" prognostic model with models – components of the selected computer tools. Presentation of this concept was preceded by the definition and characteristics of maintenance key performance indicators. It also presents a requirements and method of KPIs selection.

KEY PERFORMANCE INDICATORS – INTRODUCTION TO THE PROBLEM

According to [4] or key performance indicators (KPI - called Key Performance Indicators) are used as metrics for evaluating the implementation of the objectives of the organization. According to [3] obtained the values of these indicators allow the directions of technical - organizational activities to make them compatible with the designated company's business strategy. They allow to determine the stage of development at which there is the organization. They also allow to determine whether the organization has adopted a goal that is achieved in an appropriate manner and to indicate when it has reached. With the help of indicators, there are opportunities to optimize time, cost and activities, as key aspects of the maintenance function [3]. According to [1] the effective implementation of changes in the organization is conditioned by selection and implementation of appropriate KPIs and also conducting analysis and inference on the basis of them. Hence KPIs affect the final result in the form of savings and exploitation and organization benefits [1].

According to [4] key performance indicators should be:

- specific,
- measurable,
- prone to express their values over time by trend,
- reliable,
- measured because of the specific achievable goal,
- profitable due to their use.

According to [1, 8] KPIs should be used in:

- measurement of the current state (status),
- comparisons (internal and external benchmarking),
- assessing the effectiveness,
- diagnosis (analysis of strengths and weaknesses),
- planning for improvement,
- monitoring the developments and progress,
- motivating staff.

Key performance indicators are subject to standardization. They were included in the standard [8]. This standard describes a system for the management of maintenance key performance indicators for the measurement of the functioning maintenance including factors that are economic, technical and organizational aspects in order to assess and improve the effectiveness and efficiency in the organization. According to [8], this system should be used because of the need to achieve excellence in the handling of technical means.

Selection of indicators for the evaluation of the functioning maintenance, including their number and subject and method of measurement will be conditioned by several factors. The first is their purpose, which is indicated for the user. Depending on the level of the organizational hierarchy another data are needed. As a rule, it is assumed that the number of KPIs should decrease when going on ever higher levels of organizational hierarchy. The level of this hierarchy is also linked to the character of these indicators. At the lowest level (primary, called "shop floor") there will occur indicators in different configurations (including indicators having technical and/or organizational and/or economic character), but mainly technical indicators. The recipients are both production and maintenance workers, who analyze the indicators in terms of current effectiveness, failure frequency and quality. However, from the standpoint of the management indicators will be primarily economic and organization [1].

THE CONCEPT OF METHOD OF EVALUATION OF THE FUTURE STATE OF THE ORGANIZATION IN THE AREA OF USING AND MAINTENANCE OF TECHNICAL MEANS

Both the calculation of maintenance key performance indicators, as well as simulation and forecasting of future values of these indicators will need a tools recording data on using and maintenance of technical means and also methods and tools for data processing.

Therefore, the method was proposed to assess the future state of the organization in the area, which is the subject of consideration. It consists of the following supporting techniques:

- Geographic Information System (GIS),
- Computer Maintenance Management System (CMMS),
- Reliability Analyses Systems,
- Computer Systems supporting forecasting in maintenance management.

Geographic Information Systems

GIS systems are most often used in maintenance management in order to implement the following tasks [9]:

- identification of failure reports and classification of work related to the removing failure effects,
- planning jobs, i.e. overhauls, inspections, lubrications,
- planning detailed tasks within the breakdown removal and repair work,
- ensuring technical means, material and human resources necessary to carry out tasks,
- organization of emergency and planned work,
- long-term planning of exploitation activities,
- financial, time, material calculations material and occupation of land associated with the performing work,
- control of technical means through the use of such monitoring of selected parameters of their work or inspection.

To achieve the above mentioned activities the individual layers of the GIS system most often collect data about exploited technical means/their components. They also record data on events, processes and associated resources, resulted from the technical mean operation and associated with geographic locations for which data are stored in the databases of mentioned GIS systems.

According to the novel method, proposed by the author of the article and described in [10] the GIS system should be supplemented with additional layers, each of which will contain data on interactions on the exploited technical means. Knowledge of specific interactions, together with their scale may provide a basis to determine the functions performed by the technical mean (where the description of the function would provide the context for activities associated with specific interaction). The effects of functions will be abnormalities resulting from their realization (failures, breakdowns, etc.), together with certain causes, effects and consequences.

The example in Figure 1 illustrates the use of GIS in managing the maintenance of the water supply network. The screen system in the legend on the left side of the map lists the degrees of influence of mining damage: I, II and III. Moreover the colors: pink, blue and gray were assigned to these degrees. These interactions provide the operational context, which is part of the description of the specific function of the water supply network.

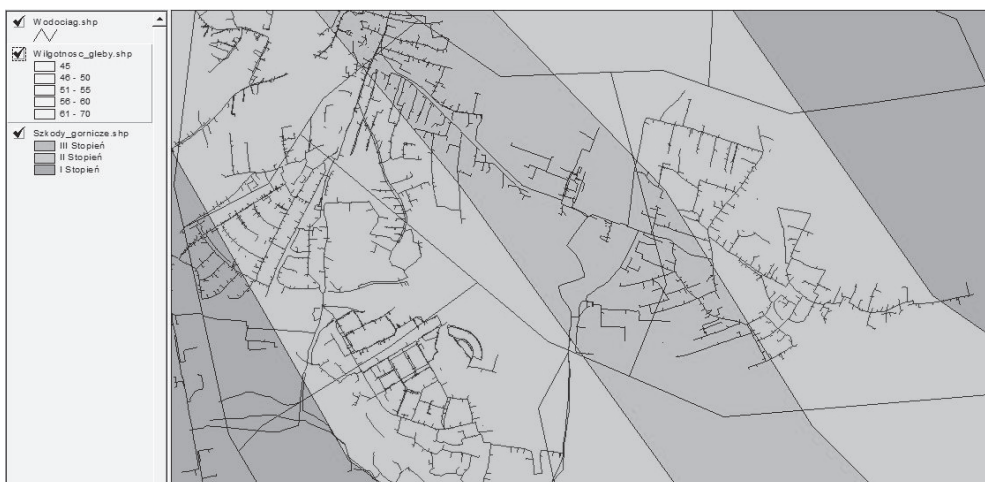


Fig. 1. Map in GIS system illustrating applying layers: „Wilgotność_gleby” (“Soil moisture”) and „Szkody_górnictwa” (“Mining damage”)

The approach taking into account the data on the functions of technical means, as well as failures due to their realization and their causes, effects and consequences will allow more effective interpretation of the actual or forecast of values of the maintenance key performance indicators .

Under the proposed concept each layer of the GIS system may contain information stored with the following models:

- points,
- lines,
- polygons.

Computer Systems Supporting Maintenance Management

There are the following systems supporting maintenance management, which might be used for forecasting KPIs values [5]:

- maintenance tools – most often Computer Maintenance Management systems (CMMS) or Enterprise Asset Management (EAM) are used,
- computer tools of enterprise – these systems class is represented by Enterprise Resource Planning systems.
- The upper mentioned systems allow primarily to collect data, necessary to compute KPIs values. Among these data it is possible to distinguish:
 - data on exploited technical means,
 - data on events, resulted from technical means exploitation,
 - data on exploitation processes.

Systems having ready solutions for computing KPIs values are EAM class tools. The example of this systems is InfoEAM (D7i), which supports tasks in the following areas [7]:

- scheduling preventive lubrications and assignment of resources where they are mostly useful,
- determining the place where it can cause a breakdown of machines/devices which are assets and determining the reasons for these failures, as well as planning alternatives,
- reliability/risk management – prediction of prediction of possible problems with the reliability of machines/devices, prevention of these problems,

- resources/warranties – reduction of inventory and supply costs and obtaining charges for warranty claims,
- strategic planning – asset management of company to achieving the corporate objectives of the effec-

MTBF i MTTR							2009-02-10
Dla : luty 2007							
Dane dla wydziału AV							
Podsumowanie dla wydziału AV							
Czas produkcji	Czas napraw [h]	Czas awarii [h]	Ilość awarii	Ilość maszyn	MTBF	MTTR	
24 480,00	91,32	242,89	84,00	51,00	291,43	2,89	
Dane dla wydziału EC							
Podsumowanie dla wydziału EC							
Czas produkcji	Czas napraw [h]	Czas awarii [h]	Ilość awarii	Ilość maszyn	MTBF	MTTR	
90 216,00	129,94	289,58	113,00	182,00	798,37	2,56	
Dane dla wydziału EP							
Podsumowanie dla wydziału EP							
Czas produkcji	Czas napraw [h]	Czas awarii [h]	Ilość awarii	Ilość maszyn	MTBF	MTTR	
65 280,00	334,58	1 191,32	207,00	136,00	315,36	5,76	
Dane dla wydziału IN							
Podsumowanie dla wydziału IN							
Czas produkcji	Czas napraw [h]	Czas awarii [h]	Ilość awarii	Ilość maszyn	MTBF	MTTR	
6 720,00	10,58	5,15	5,00	14,00	1 344,00	1,03	
Dane dla wydziału TR							
Podsumowanie dla wydziału TR							
Czas produkcji	Czas napraw [h]	Czas awarii [h]	Ilość awarii	Ilość maszyn	MTBF	MTTR	
18 720,00	26,81	33,84	28,00	39,00	668,57	1,21	

Fig. 2. Report of Infor EAM system including specification of values of indicators: MTBF (Mean Time Between Failure) and MTTR (Mean Time to Failure) [6]

Reliability Analyses Systems

The purpose of the tool of class in question is to obtain calculations and simulations of reliability, for the technical means described by the reliability block diagrams (being representation of reliability structures), maintainability and availability (which are the sizes necessary for the calculation of the KPI). Getting the measures values of reliability distributions is possible through the use of reliability block diagrams representing the reliability structures: serial, parallel, mixed, etc.) as well as of reliability characteristics for each component of a technical mean, obtained based on the description of the exploitation process, represented by model of exploitation process as a sequence of events (with the zero-time of renewal, with a finite time of renewal or with waiting for renewal). The screen of system of the class in question – BlockSim is illustrated in Fig. 3.

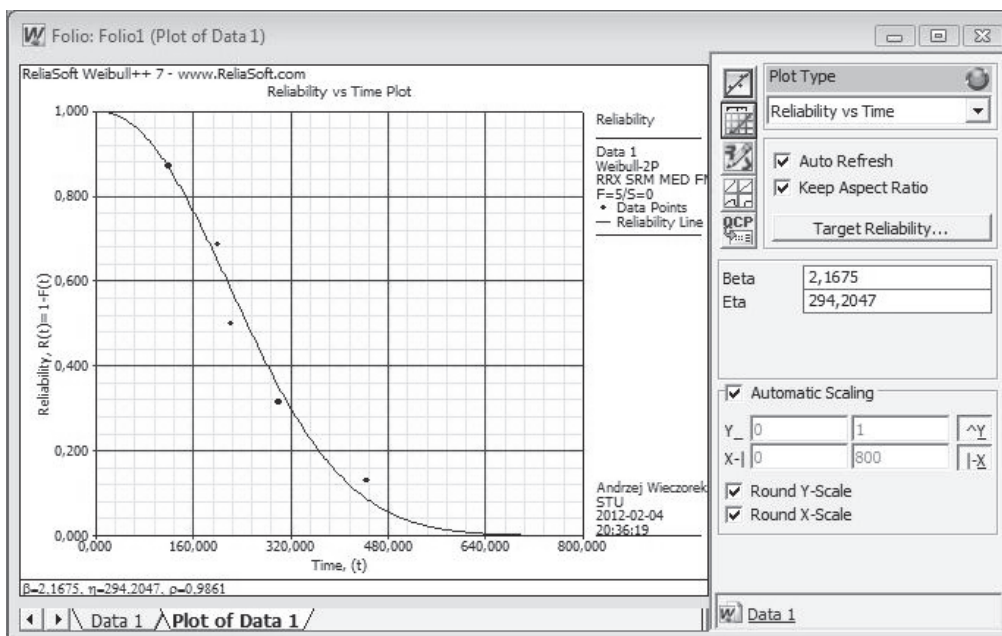


Fig. 3. Screen of BlockSim system of Reliasoft firm (system allows to deliver the selected measures, necessary to compute KPIs)

Systems supporting forecasting

Among the tools supporting the forecasting that could be used to assess the future state of organization in the area of using and maintenance of technical means it is possible to distinguish:

- computer tools, which conduct various statistical analyses (including spread sheets),
- tools for predicting the reliability of technical means (an example can be ReliaSoft's Lambda Predict system).

Due to the different needs of forecasting of the values of individual indicators, in performance of proposed supporting tools to support there is possibility to use the following methods [2]:

- methods of analysis and forecasting of time series - the most widely used models of this group are: methods of moving average, exponential smoothing, analytical and adaptive models of development trend, periodic component models,
- "cause - effect" forecasting methods - the methods of this group include econometric methods or symptomatic methods (last mentioned methods are used when the theory does not give rise to the construction of the cause - effect relationship model and empirical studies show a correlation between the variables under consideration; these models do not have the diagnostic features, but can be used to determine the forecasts),
- analogue methods – it is possible to distinguish one of this method: a method of biological analogies, the spatial analogies method and historical analogies method,
- heuristic methods - this group of methods include brainstorming, Delphic method and the method of cross influences.

EXAMPLE OF USING SELECTED FORECASTING METHOD IN THE ASSESSMENT OF THE FUTURE STATE OF ORGANIZATION IN THE AREA OF USING AND MAINTENANCE OF TECHNICAL MEANS

Management of many water and sewage supply companies are asking themselves: what availability increase in the term: years, 3 years etc. will be as a result of the overhaul of selected sections of water network. In order to assess this availability there can be use the indicator whose value would be calculated using the following formula:

$$D = \frac{MTBF}{MTBF + MFOT} \times 100 \quad (1)$$

where:

- D – availability,
- MTBF – mean time between failures,
- MFOT – mean forced outage time.

Mean Time Between Failures can be computed using the following formula:

$$MTBF = \frac{CD}{LZD} \times 100 \quad (2)$$

where:

- CD – total time of machine/installation performance,
- LZD – total number of unintended events,

Mean forced outage time MFOT can be computed using the following formula:

$$MFOT = \frac{TNAP}{LZD} \quad (3)$$

where:

TNAP – total time of repair,

LZD – total number of unintended events.

The total number of events, and repair execution times for individual sections of water network (to calculate the mean forced outage time MFOT) can be established on the basis of data collected in the CMMS system (described in chapter 3 of article). While mean time between failure can be calculated with the use of Weibull ++, which is ReliaSoft's system based on data received from the CMMS system. The system screen Weibull ++ is shown in Figure 4.

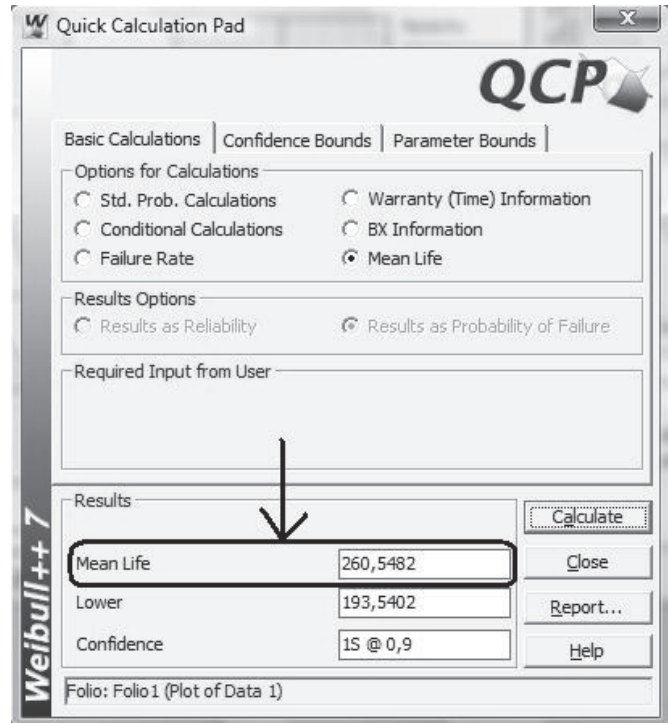


Fig. 4. A screen of Weibull++ system illustrating a method of computing Mean Time Between Failure (MTBF)

There is a need for association of received values of availability indicator with selected technical means assigned to particular geographic locations. There is also a need to compare the value of this indicator, obtained for these locations. It is therefore justified to use the forecasting methods that use cross - time series for the evaluation of maintenance organizations state. Cross - time series are created by the G time series of variables describing the K objects. Information matrix can be written as a matrix of blocks, each block contains a multivariate time series, characterized by K object:

$$Y = \begin{bmatrix} Y^1 \\ \dots \\ Y^K \end{bmatrix} \quad (4)$$

where:

$$Y = \begin{bmatrix} y_{11} & y_{12} & \dots & y_{1n} \\ y_{21} & y_{22} & \dots & y_{2n} \\ \dots & \dots & \dots & \dots \\ y_{G1} & y_{G2} & \dots & y_{Gn} \end{bmatrix} \quad (5)$$

where:

Y_{Gn} is a state of G variable in while or term t
($g = 1, \dots, G; t = 1, \dots, n$).

Values of cross – time series could be listed in table 1.

Table 1
Number of failure of water network with the selected causes, appearing in street location

Street	Variable	Symbol	Number of failures in 2010 year		
			January	February	March
Street 1	Corrosion of pipe	Y_1	1	2	2
	Mining damages	Y_2	2	3	1
Street 2	Corrosion of pipe	Y_1	2	2	4
	Mining damages	Y_2	1	0	2

Obtaining forecast of the maintenance organizations state will become possible as a result of implementation of the selected forecasting model such as the Excel spreadsheet.

Analysis of the received values of predictions with the analysis of interactions (for water supply network the interactions may be: corrosive soil environment, mining damages, stray current, etc.) about which data is available in the GIS system will enable an explanation of obtained values of the indicators.

CONCLUSIONS

Assessment of the future of activities in the area of using and maintenance of technical means is possible with the use of indicator values, calculated on the basis of current and historical data about objects, events, and exploitation processes, as well as appropriately selected methods based on simulation and forecasting. Challenge is to interpret values of the simulation/forecasts for these indicators, taking into account their multiplicity, and the fact that their values may change not only in time but also in space domain. Hence it is necessary to have techniques that allow for the calculation, but also skillfully interpret the received data.

An example of this technique is the integrated support system described in the article, which, thanks to methods

thanks to implemented (including Cross - time-series analysis method), and not only data on technical means, but also on the interactions of these means (accumulated in the databases of GIS) allows not only to calculate the forecasts of indicator in the selected term, but also the rational justification of these forecasts. This approach to the exploitation of technical means guarantees the selection of appropriate using and maintenance policies of these means. However, it requires appropriate preparation of description of the environment of these means. This environment may constitute not only the interactions of a technical nature. His participant is also human, whose impact on the performance of the technical mean must be taken into account.

The developed concept of modeling has become an inspiration to pursue further research on simulation and forecasting models of assessment of the organization state, taking into account the aspect of space.

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dr inż. Andrzej Wieczorek
Silesian University of Technology
Faculty of Organisation and Management
Institute of Production Engineering
ul. Roosevelta 26, 41-800 Zabrze
e-mail: andrzej.wieczorek@polsl.pl