MODERN SYSTEMS SUPPORTING MAINTENANCE OF MACHINES

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Abstract: The paper presents programs of computer aided maintenance of machine operation; an analysis of the changes taking place and assessment of their suitability has also been performed. Computer systems aiding the management of machine operation, selection an adequate system as a way to the enterprise success have been considered, too. General classification of the Computerized Maintenance Management Systems (CMMS) has been presented. Various kinds of computer aided machine operation maintenance systems have been presented. The strategy of developing the machine operation maintenance development, including the utilization of Business Intelligence in the systems of CMMS class, as well as the availability of the CMMS in Poland have been described, too. Most of the CMMS systems available in Poland have been presented. The following applications are discussed: Betacom, Aretics, Comarch, EUROTRONIC 2000, Overhaul and Exploitation Economy, IFS Application, CMMS Machine Program, Golem OEE System, MAXIMO, Operation Maintenance System FBD and Utilization of Machines and Devices in an Enterprise. They help to keep order in all the issues related to overhauls and operation maintenance. It should be pointed out that, when the TPM (Total Productive Maintenance) concept was introduced in enterprises, it has turned out that its efficient functioning requires implementation of a computer system to supervise and control machine operation maintenance.

Key words: maintenance of machines, CMMS, MAXIMO system, CMMS machine, Business Intelligence.

1. INTRODUCTION

It can be observed that, in recent years, the computer systems aiding the management of machine and device exploitation or operation maintenance have undergone numerous and significant modifications.

This is, to a certain extent, an effect of the users' requirements, as well as the development of information technology, both in the scope of hardware and the abilities of operational systems, as well as the newest platforms. Certainly, those factors are strongly interrelated and, in a sense, they are complementary to each other. The users' requirements are difficult challenges to the information technologies. On the other hand, their development additionally enables more and more new purposes to be realized.

2. PROGRAMS OF COMPUTER AIDED MACHINE OPERATION MAINTENANCE – ANALYSIS OF MODIFICATIONS AND SUITABILITY ASSESSMENT

In the present-day world of highly developed economy, increasing technical equipment of work can be observed. The cost of machine maintenance and machine amortization exceeds repeatedly other costs of enterprise.

At the moment, during the crisis, improvement of managing the fixed assets is, therefore a very important task due to the economical aspect. Correct functioning of the process of management of the fixed assets requires deep analysis and system approach, both in the technical and the economical aspect. The most important objective of each enterprise should be to satisfy the customer and to manufacture products at the lowest possible cost while minimizing the occurrence of failures, downtimes and operators' mistakes that is mainly the things bringing losses to the enterprise.

One of the concepts of organisation improvement in that respect is Total Productive Maintenance (TPM), which raises the value of the firm taking advantage of involving all the employees in solving the problems related to the efficiency and availability of machines and devices.

However, in this concept, as well as in many others, information and process measurements are of crucial importance. With the above statement in mind, the suitability of computer aiding of machine operation in the enterprise should be considered [1].

In the functional respect, the systems of aiding the management of exploitation and operation of machines and devices have developed from the simple CMMS programs enabling overhaul economy to be put in order in a production enterprise to complicated systems aiding the Enterprise Assets Management (EAM) and Software Assets Management (SAM) [2].

The scope of those systems activity comprises not only the strictly production aspect, but their functioning has been extended to such aspects as: the broadly understood infrastructure of the enterprise, its computer infrastructure, internal and external transport, supply of parts

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and materials necessary in the overhaul economy, external contracts etc. [3].

Of course, the entire systems development concerns not only the substantive scope of action - a very important development proves the scalability of systems. At present, advanced systems allow the extension of the many plants of one company often scattered around the world, many languages, time zones, currencies etc. These installations make it possible to optimize the management of the assets of the organization [3].

Regardless of the size of the organization it is possible to improve the availability and performance of assets generating income. Using management systems can reduce time and maintenance costs and ensure availability of necessary spare parts while reducing inventory and improving supply, as well as the organization's external contracts [3].

It is important that the amount of information available in the system comprising historical data, current data and future data (calculations, plans) makes it possible to manage the assets during the whole cycle of the product "life". Thanks to the fact that it is possible to indicate the critical elements of equipment and to precise information on what spare parts will be necessary and when, the actual cost of possessing the assets, as well as the ways of its reduction can be determined. As a result, management of the assets can start even before a machine comes to the enterprise and starts functioning. Accurate matching of materials and assembly instruction will significantly facilitate the utilization of the machine during its functioning. By creation of a visual catalogue of the assets possessed (MAXIMO Illustrated Parts Catalogue) in accordance with the description standards adopted in the whole organization (Standard Modifier Dictionary^{T}M), the system enables the employees to move the structure of the assets completed with detailed drawings/diagrams of its elements and, due to that, quickly find an object, determine the items to be repaired and find them in the chain of supply. In the whole cycle of the assets functioning in the organisation, the present-day systems supporting the operation maintenance management facilitate the activities involved in management of labour, planning and scheduling [3]. It is important that those programs:

1. Intercept and analyse the data coming from the monitoring systems; they also generate work orders and book relevant parts and materials basing on the current state of equipment, its working time or preventive maintenance schedule.

2. Possess developed possibilities of organizing internal flow of information in accordance with the adopted organisation diagram (workflow) incorporating financial approvals, hazards, safety, and the like.

3. Realize special requirements like: certification, electronic signature, call centre, and the like.

4. Offer unlimited mobility by the application of solutions working on any portable computer devices.

5. Enable integration with many financial - book keeping and personal systems via dedicated integration modules or special tools type "integration gateway".

6. Combine maintenance and production by integration with production systems of industrial automation.

7. In a broad scope, they automate the processes of spare parts and materials supply. Thanks to the

e'commers mechanisms applied at the level of operation maintenance service they render considerable reduction of material costs. Orders generated directly on the basis of the state of equipment, maintenance schedules and device working schedules can be sent directly to the suppliers by the electronic way, which makes it possible to deliver them at the desired time to the indicated place [3].

3. PREMISES OF THE APPLICATION OF COMPUTER SYSTEMS SUPPORTING MACHINES MAINTENANCE

In many cases, the total implementation cost is the factor determining the selection of a system, as well as its advancement and complication. Everything depends on the amount of financial means intended for the implementation of one of the solutions under discussion.

It should be kept in mind that most large concerns use complex new generation solutions additionally aided by specialized systems dedicated to the individual fields of activity. Although, for instance, the systems of class MRP II (Manufacturing Resources Planning) or ERP (Enterprise Resources Planning), possess functions allowing for machine park management, but they are not enough complex [1].

For that reason, for many enterprises, it is necessary to implement an additional system of class CMOS (Cargo Movement Operation System) which aids the overhaul and repair economy. Thanks to that, automation of the whole process of supervision of the production line devices and equipment, as well as the other components necessary in the manufacturing process can be effected.

The necessary condition for the co-operation of those systems is the enterprise's possession of a fully integrated computer system. There is, however, a large group of small and medium enterprises who cannot afford implementation of complex computer solutions. That is why processes are aided by several small applications with narrow range, often prepared within the enterprise by its own employees. Medium enterprises can afford a corporation system type ERP, but it is often aided with small applications elaborated by themselves, but that involves drawbacks. Application system made in this way is not elastic enough, it is also necessary to manually adapt the enterprise's "own" application for the specific tasks and communication with the existing systems. Considering the above limitations, the best solution is to implement one system with full functional scope, which will provide high elasticity.

Small enterprises must answer the question, whether the activity they conduct so complicated that it requires any support of a computer system. It is often found that there is no necessity to implement complicated systems which are expensive solutions. Sometimes, it is enough to aid the enterprise with an application of narrow activity scope, directed to the firm's strategic processes.

4. UTILIZATION OF BUSINESS INTELLIGENCE IN CMMS SYSTEMS

When analysing the functionality of CMMS class systems, enabling efficient management of technical infrastructure, implemented in various enterprises, it is

worth consideration what else can be obtained within the analyses being performed and how to improve the process of planning preventive works. As the system is currently expanded, successive parts of the enterprise are computerized, and due to the large amount of data processed, the persons responsible for the analysis and reporting of information relevant to the technical infrastructure management find it difficult to effectively identify, for example, the trends appearing in the recorded problems and typical solutions [4].

Considering the examples of Polish firms, one has to keep in mind that, within one production enterprise, the number of work orders generated on the basis of problems reported and planned works exceeds a thousand documents in 24 hours. Furthermore, in many objects served by a big enterprise, effective detection (of, e.g. embezzlements within projects, overhauls, purchases or identification of subsequent areas) where costs can be reduced and, therefore gain incomes, becomes simply impossible. An interesting proposal can be the use of computer techniques named Business Intelligence, available in the market, for managing the technical infrastructure [4].

The systems of class CMMS acting on the Microsoft SQL or Oracle servers can be complemented with the so called wholesale data bases in which all the data relevant to the infrastructure management in the whole enterprise are stored. Then, with the use of such techniques as data exploration or by other mechanisms related to the Business Intelligence, the data are analysed in a detailed way.

One of the tendencies to be seen in conferences organized by various foreign branch organizations is the trial of concentrating on the data processed in actual time in infrastructure management. Due to the relatively low productivity of the systems and too large amount of data to be processed, persons in posts of authority are not able to respond to many problems reported to them. Very often, dynamic making decisions concerning everyday work of the enterprise must be effected basing on clear productivity parameters on which, for example, information portals a based; those portals take the form of a sort of enterprise control panels. The application of techniques related to the Business Intelligence in infrastructure management is possible both by means of the CMMS system and by external analytic tools. The analyses can be enriched with data from other sources. The techniques applied for the process of optimization of works can be particularly useful. Optimization is achieved by multidimensional segmentation of the problems occurring in the objects. The large amount of information difficult to analyse can be recorded with the use of industrial automation installed in the objects. One of the most important objectives of the technical service management is to minimize the number of failures by increasing the amount of preventive works, which can be achieved by taking advantage of the above mentioned analyses and forecasting the occurring problems in technical infrastructure. What's more, Business Intelligence makes it possible to analyse the effects of previously made decisions, e.g. the effects of undertaken preventive actions [4].

The possibility of reducing the total cost of infrastructure exploitation, optimisation of the preventive work

planning process, creation of the best ways of management, supporting the decisions made by the managing staff, advanced analysis of the history of the works performed incorporating the most frequent trends, dynamic budget management, monitoring of the Key Performance Indicators (KPI) realised in actual time and bases for a discerning analysis of the reasons of problems occurring and, consequently, the possibility of undertaking adequate actions in actual time – these are only a number of advantages of using the Business Intelligence. It is also important that the application of the tools mentioned above requires adequate preparation and planning of the structures processed by the CMMS system, as well as the data coming from external sources, such data as the already mentioned industrial automation. The application of a large number of vocabularies used in all the modules of the computer system (e.g. in detailed recording of works related to the utilization of human and material resources or in planning) significantly facilitates the preparation of later analyses [4].

5. AVAILABILITY OF THE CMMS SYSTEMS IN POLAND

Although the CMMS/EAM systems are just starting their career in the Polish market, the offer is very rich as regards the functional aspect. Both small and medium or large enterprises can select a system to meet their requirements without excessive economic load.

In the Polish market, over a dozen applications are offered which can be classified as CMMS/EAM. Those are both specialized programs for small and medium enterprises (e.g. Agility) and large, included in larger systems (e.g. ERP software modules). In the USA, such applications are supplied by over 100 producers, a part of which in the model of Application Service Providing (ASP) – hiring of applications. No doubt, for a given enterprise, the price of such a program is important. At the moment, the prices of the CMMS systems vary significantly ranging from low sums for a stand of a small system up to several thousand dollars for one licence of a network version. In large systems or ERP system modules, the prices are negotiated and the system itself is implemented in the enterprise. The systems of operation maintenance are complemented by other programs and devices. Those can be, first of all, interfaces for the service of devices and systems of bar codes, portable terminals (palmtops), devices analysing the condition of machines (measurement analytics), control devices (industrial automation). Further in the present text, most of the CMMS systems available in Poland will be presented. They help to keep order in all the issues related to overhauls and operation maintenance.

Betacom is a solution based on software of API Maintenance Systems A/S, creator of dedicated and specialized solution in the scope of overhaul systems. The system is based on complex service of the overhauling process and maintaining devices and machines operation. The modules comprising prevention and working orders are tools for planning, preparation, cost estimation and execution of maintenance and overhaul works. Elaboration of preventive actions and association of them with the devices make it sure that the proper works will be

performed at adequate time. Inspections and other maintenance actions can be planned on the basis of dates, measurements or respective events [5].

Aretics is a tool for aiding the work management in the operation maintenance department. It allows for work planning and scheduling, collection and analysis of devices maintenance history in order to improve task planning and to convert to preventive maintenance, for coordination of the operation maintenance department actions with the production plan, optimization of the spare part store, cost analysis, Pareto analysis. The main software is also provided with a simplified customer – Aretics Injector and server software – Aretics Server. Aretics Injector is a simplified customer for reporting failures, taking tasks to be executed, working time reports and recording the articles and spare parts taken from the store. A detected failure is recorded in the system with the use of the customer's software. The reporting person does not have to know who is to take the responsibility for rectifying the failure or performing the repair - Aretics deals with it automatically. Each user can then easily see what is done about the reported failure. Aretics Maintenance uses the Microsoft SQL Server data base. In order to activate automatic creation of spare copies, Aretics Server can be installed. This program includes a server of printers which distributes the coming work orders to be printed on the printers located nearest to the persons responsible for their realisation. The coming tasks can also be sent to e-mail addresses or to cell phones as SMS. The planned orders can also be automatically sent to external firms [5].

Comarch is a full aiding system for enterprise management. It is provided with an OTS (Overhaul and Technical Service) module which completes the so far existing functionality of the Compact Disc Novelty system (CDN) – it manages the elements characteristic of the CMMS systems. In particular, it allows for planning, servicing and calculations related to the operation maintenance in production, municipal or transport enterprises. It enables more rational managing of human resources and technical stores. Due to integration with controlling, it aids the management of overhaul and machine operation maintenance budgets, actual data on time consumption of individual actions, as well as their cost. It also completes the functionality of the Fixed Assets module in the scope of the enterprise's property [5].

EUROTRONIC 2000 is an advanced tool for monitoring the cost of fixed assets maintenance depending on the function it performs. D7i (Datastream7i) aids the management of infrastructure maintenance, modernisation and investment management, material economy, supplies and controlling, supervising all works related to the exploitation of technical objects. The D7i system includes all the functions necessary to maximize the effectiveness of the assets and resources of the technical sections and to minimize the cost of administration, overhauls and material economy [5].

Overhaul and Exploitation Economy is a module of integrated packet of systems for management of the technical and technological area of the enterprise, i.e. of the TP-COMMANDER packet. The program module, Overhaul and Exploitation Economy, serves for full management of the processes of repairs, maintenance,

and inspections of machines and devices in the scope of listing, work planning and work monitoring. In a special scope, servicing can comprise machines and devices included in the enterprise's equipment and supervised by the technical, exploitation departments and operation maintenance department (the Chief Mechanical Department, Chief Power Engineer Department, Transport Department). For most of those devices in the basic scope, the system aids keeping permanent supervision of the necessary works being performed according to the strictly planned, long term schedule, with the possibility of current generation of protocols of their execution [5].

IFS Applications ensures expanded functionality of the ERP. It comprises, among others, the IFS Overhauls module which the plays the role of a CMMS subsystem in the whole system. The IFS Overhauls consists of about 10 modules supervising the devices as well as overhaul and maintenance works. Module IFS/Complex Overhauls, Repairs and Inspections (MRO – Maintenance, Repair and Operations) enables detailed insight into the structure of costs involved in the overhaul, repair and inspection actions. The solution includes the service of agreements with customers, work scope planning, inspections, dispatching and invoicing. The module is included in the fully integrated solution type MRO elaborated for independent enterprises specialised in repairs and overhauls, original equipment manufacturers (OEM) and for the users of complex structure installations and devices. MRO covers a wide range of actions including operation maintenance, planned overhauls, workshop repairs and independent repair centres with full scope of service [5].

CMMS Machine Program is an expert system giving information on the machine park, equipment and vehicles to the largest possible group of people dealing with operation maintenance in the enterprise. The Machine program is focuses on the creation and queuing of action schedules, both periodical and current or preventive ones, and recording full history of failures and exploitation together with detailed descriptions of them. It also allows for monitoring all formal actions related to the machine park, such as, for example, investigations of the Technical Supervision Office [5] This application can be associated with **Golem OEE System**. This last one is designated for operation monitoring of machines and devices and provides information on the operation time, downtimes, volume of production in the context of machine state. System calculates the coefficient of efficiency (OEE) and is able to visualise the state of machines (Fig. 1).

MAXIMO system is a tool for managing all the elements of the system of exploitation and operation maintenance, beginning from the preparation of orders for works to be executed, through work planning to as far as the realisation of tasks involved in completion of resources and storage economy. The system also offers a specific way of preparing schedules for selected tasks by utilization of the module named MAXIMO Scheduler, an interactive planning tool. The MAXIMO system makes it possible to progressively implement the packet of "healthy" management principles known as Complex Manufacturing Management in the exploitation arrangement (Fig. 2). In particular, the MAXIMO enables col-

lection of coherent and up-to-date data files constituting the basic element of the principles of TPM (Total Productive Maintenance [5].

The Operation Maintenance System - FBD is a computer solution intended for the operation maintenance services. Its major objective is automation of works involved in: management of the assets of technical infrastructure, conduction of overhaul economy, performing technical inspections and machines maintenance, storage economy of operation maintenance department, managing orders for materials and spare parts, reporting and generation of statistics. It is a totally polish product. It has been built on the basis of experience and demands of the operation maintenance staff of manufacturing enterprises with various production profiles. Unlike American and West European programs, this program does not include functions which are useless under polish conditions. The functional modules of the program are as follows: Machines and devices, Spare parts and materials, Current/Emergency works, Preventive/planned works, Employees, Stores, Co-operating firms, Offer inquiries, Orders, Projects, TPM reporting, Financial

reporting, Statistics/diagrams, Warning system, Production effectiveness (Overall Equipment Effectiveness - OEE) [5].

Utilisation of Machines and Devices in an Enterprise is software aiding the recording and monitoring of the technical condition. The program allows for monitoring of the technical condition of the production equipment in any enterprise and makes it, among other things, possible to currently record the machines in the firm, monitor the terms and elaboration of documentation (e.g. technical acceptance protocol, declaration of conformity) and to assess the technical condition of the production equipment in the enterprise's possession, record the history of repairs and overhauls of machines in the enterprise, monitor the terms and elaborate inspection plans for each device. The program consists of 11 modules implementing the process descriptions and records of matters relating to the devices. It is possible, therefore, to create the directory up to date equipment and check its condition. The basic module is the Base of Machines which records information about the devices. Module
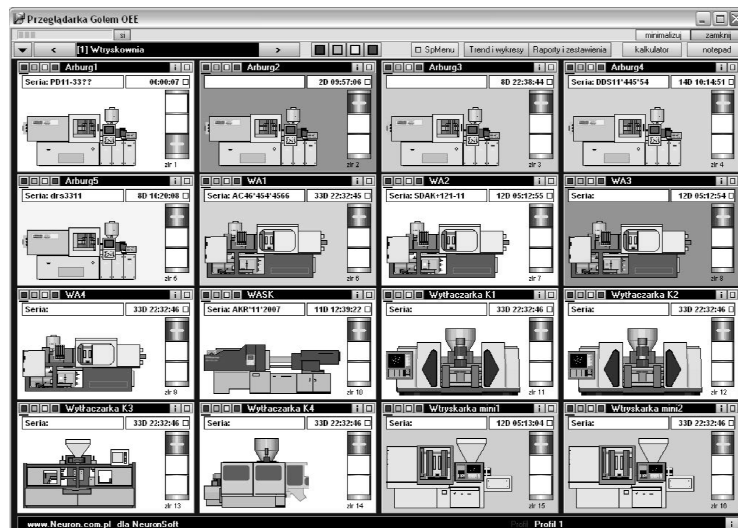

Fig. 1. The example of the visualisation of the state of machines edited by Golem OEE System [source: *http://www.neuron.com.pl.pliki/golem_oee.pdf*].
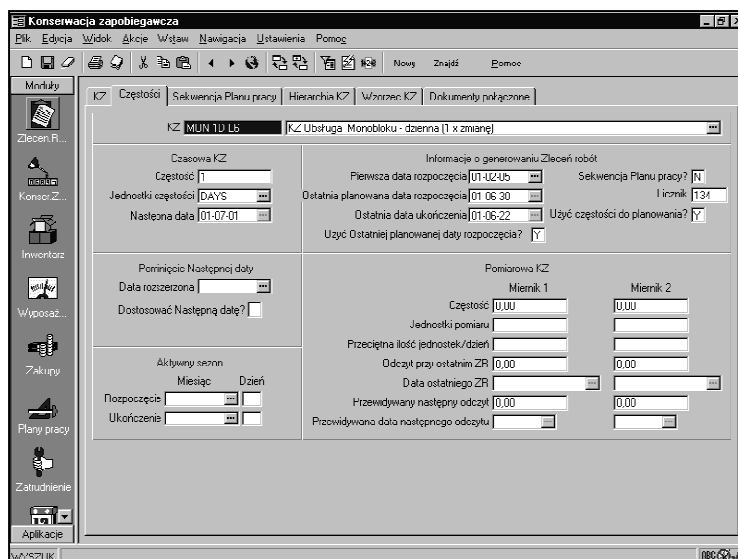

Fig. 2. An example of preventive maintenance card of MAXIMO.

Employees contains a base of employees related to the devices (service). In this base, information about an employee including his qualifications and authorizations is placed. In module Inspections information about inspections is recorded (inspection scope, works performed, recommendations and repairs. Module Notifications makes it possible to plan and remind the terms related to machines and devices. The program makes it possible, too, to monitor the costs involved in service of the machine park. Each module enables creation of reports including out prints of the record of hours the device has worked. In addition, the program contains prints necessary when adapting the machines for the European requirements (e.g. conformity confirmation, technical acceptance protocol, declaration of conformity), as well as information on Machine Directive [5].

Since January 1, 2006, all machines and devices must meet the requirements of the European Union Tool Directive. Manufacturers and users must provide proper technical conditions of the devices and prepare completely new technical documentation. Failure to fulfil the above obligations in due time will result in serious consequences – from financial penalties, through production stopping to closing of the enterprise.

6. CONCLUSIONS

Summing up, it should be pointed out that, when the TPM concept was introduced in enterprises, it has turned out that its efficient functioning requires implementation of a computer system to supervise and control machine operation maintenance.

The question arises, therefore, how complicated tool such a system should be. In the analysis performed in the previous part of this chapter, features necessary or useful, depending on the firm size, have been determined. Here, the situation of small enterprises having little requirements concerning the possibilities of programs dedicated for management of the overhaul and repair economy, could be taken as an example. The expectations of medium and big firms are close to each other. In the case of those enterprises, the programs intended for them must be provided with more advanced functions. Due to that, most class MRPII/ERP systems are found insufficient for corporations possessing differential and complicated machine park. Then, it is necessary to introduce additional programs aiding operation maintenance, e.g. programs of class CMMS.

One of the solutions could be to add the missing functionalities related to the activities involved in overhaul and repair economy to the class MRPII/ERP systems. It would allow for making them, in fact, systems of complex management. However, it has to be kept in mind that no program will generate anything by itself. It becomes a useful tool only due to the commitment and awareness of the users. It is the possession of an adequate system that allows for certain analysis of arising situations and results in better reliability and availability of the equipment and, consequently, leads to cost reduction and improves the enterprise's competitiveness.

It is absolutely sure that, with the constant development of the computer systems aiding management, introduction of them to the service of many enterprises is inevitable. Just as in other cases, the scope of application will certainly grow, from the simple CMMS systems which control the overhaul economy, towards advanced systems. It can be inferred from the analysis of available information on the implementations of the management systems (e.g. MAXIMO). In the first stage, computer systems aiding management of machine exploitation and operation maintenance have been applied in large enterprises.

MRO Software reports concerning implementations in transport (trucks, airplanes and water transport) indicate that the most interest is shown by organisations possessing many cars or planes. This is due mainly to the possibilities of expanding the system in the scope of meeting the strict formal requirements. The interest in the systems shown by economic entities in many countries indicates that significant progress is to be expected soon, also in implementations in the field of servicing machines not well known so far.

The CMMS class systems are often implemented in enterprises attempting to obtain a certificate - most often in the field of quality, safety or environment. Hence, technical solutions are aimed at aiding actions which allow for putting in order, documenting and proper conduction of all works according to the principles and guidelines resulting from the corresponding standards.

It must not be forgotten, however, that the achievement of the above mentioned magnitudes does not take place "automatically" as soon as the decision of the purchase and implementation of the system is made. Such a system should be rationally selected, implemented and utilised. It is only complex realisation of the three postulates that guarantees modern management of the technical system and, consequently, improvement of the effectiveness of functioning of the technical objects.

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