Article citation info:
JURCA V, ALES Z. Maintenance management systems in agricultural companies in the Czech Republic. Eksploatacja i Niezawodnosc – Maintenance and Reliability 2012; 14 (3): 233-238.

Vladimir JURCA
Zdenek ALES

MAINTENANCE MANAGEMENT SYSTEMS IN AGRICULTURAL COMPANIES IN THE CZECH REPUBLIC

SYSTEMY ZARZĄDZANIA UTRZYMANIEM RUCHU W PRZEDSIĘBIORSTWACH ROLNYCH W REPUBLICE CZESKIEJ

The purpose of this paper is to describe different maintenance management systems being used by Czech companies with a view to the agro-industrial complex in recent years. The paper focuses on maintenance management systems supported by information system (IS) and their implementation in companies. The use of IS helps to create a variety of scenarios with an emphasis on the need for analytical instruments processing data integration in order to improve the efficiency of the maintenance system and identify its weaknesses. While the maintenance management information system (MMIS) is widespread within the agro-industrial scope in the manufacturing industry, in primary agricultural production and agricultural machinery servicing, it has yet to be utilized. The paper also describes some possible applications of MMIS in the sphere of the agro-industrial complex, the differences between their applications and the potential use of MMIS in the case of fully or partially outsourced agricultural equipment maintenance.

Keywords*: maintenance management systems, information system, preventive maintenance, maintenance costs.*

Przedstawiona praca ma na celu opis różnych systemów zarządzania utrzymaniem ruchu stosowanych w ostatnich latach przez czeskie przedsiębiorstwa ze szczególnym uwzględnieniem zakładów rolno-przemysłowych. W pracy główną uwagę skupiono na systemach zarządzania utrzymaniem ruchu wspieranych przez systemy informatyczne (IS) oraz na problemie ich wdrażania w przedsiębiorstwach. Użycie systemu informatycznego pomaga w tworzeniu różnych scenariuszy, przy czym nacisk kładzie się na zapotrzebowanie na instrumenty analityczne służące do integracji przetwarzanych danych w celu polepszenia wydajności systemu utrzymania ruchu oraz rozpoznawania jego słabych punktów. Podczas gdy użycie systemów informatycznych wspomagających zarządzanie utrzymaniem ruchu (ang. maintenance management information system, MMIS) jest powszechne w zakładach rolno-przemysłowych przemysłu wytwórczego, podstawowa produkcja rolna oraz obsługa maszyn rolniczych czekają jeszcze na ich wdrożenie. W artykule opisano także możliwe zastosowania MMIS w zakładach rolno-spożywczych oraz różnice w aplikacji i potencjalnym wykorzystaniu MMIS w przypadku prac w zakresie utrzymania ruchu maszyn i urządzeń rolniczych całkowicie lub częściowo zleconych firmom zewnętrznym.

Słowa kluczowe*: system zarządzania utrzymaniem ruchu, system informatyczny, obsługa zapobiegawcza, koszty obsługi.*

1. Introduction

The maintenance status of Czech companies has changed considerably in recent years in favour of maintenance, which previously was often seen by management as a kind of necessary evil, which only draw from corporate resources. Today, in prosperous companies maintenance has become one of integral processes, where it is necessary to apply similar principles of quality management, such as in manufacturing and all other areas of business management. One of the important principles of quality management is a "continual improvement", which has to be a sustainable objective of any organization. [2]

Successful quality management in general, including the maintenance management system is based on full documentation of all related activities. Anyone who deals with maintenance issues is aware that well-functioned efficient maintenance system must be planned and transparently documented. It must be clearly determined when, who and how to carry out the maintenance. It has to be back indictable how, by whom and when the maintenance was performed, at what costs was the maintenance performed and what is the quality and reliability of the whole system and its elements. There are many indicators which should be documented and frequently analyzed and therefore for the most companies it is necessary to use the information system. Maintenance management information system (MMIS) is designed to simplify and standardize documentation processes of maintenance data. Beside that such an information system promotes the process approach and system approach to management which enables a continuous improvement of maintenance. [5] Maintenance information system in particular allows decision making based on facts, which is accessible in the system and which promptly provides information in order to make a decision on the rational basis.

The MMIS use is already widespread in the Czech manufacturing industry. The MMIS was first introduced in the mid 90's in automotive and related sectors. At the turn of the century the MMIS began to be utilized also in agro-industrial complex (dairies, bakeries, sugarhouses, breweries etc.), but in the enterprises with primary agricultural production the MMIS has been used only exceptionally although the agricultural machinery is getting to be more computerized and more expensive in terms of their purchase and operation.

A well-functioning maintenance system can significantly reduce operating costs, particularly in the following areas:

- Enhance the reliability of production equipment and thus improve its elementary properties (especially availability, safety and durability) [7]
- Significantly change the ratio between maintenances after failure and planned maintenances in favour of planned mainte-

nance and thus reduce downtimes and subsequently increase machine utilization
- Essentially minimize the number of failures and thus lower a number of maintenances after failure, thereby the consumptions of expensive spare parts (which tend to be unnecessarily drawn just during emergency breakdowns) will decrease
- Decrease of costs due to the lower overtime of maintenance personnel and cost reduction for outsourced maintenance services
- Reduction of overall maintenance cost over a long time period [4]
- Based on collecting data related to failures and their analysis – repeated failures are significantly reduced
- A number of non-conforming products will decrease and thus lower the cost of non-quality
- Furthermore, increasing the efficiency of maintenance results in reducing the environmental impacts of organization's activities and improves the safety and health at work which is the goal of the integrated quality management system.

Currently, it is already common that the maintenance management system is supported by the information system. Without support of MMIS, it is not possible to assess the effectiveness of maintenance (unreliable data) and besides that it is not possible to effectively manage and plan maintenance activities (proper data is missing). [1] If it is assumed that maintenance is supported by the MMIS, it is possible to get a number of indicators, which enable to quantify most of the benefits of MMIS - they are already certified in the industrial sector and there is no reason why the agriculture sector (despite certain specifics) should be an exception. Why such a system is not yet widespread in the agro-industrial complex?

2. Material and method

The general idea of MMIS is based on the principles of logistics management system, whose main objective is to plan, manage and control material and information flow in order to achieve the performance and economic goals. A substantial part of the logistics management system is an information system (IS), which goal is to capture, store, process and transmit data (actual and planned). It is beneficial not only for well organized documentation of the maintenance and other activities (it is a starting point, it is not desired goal), but also to save time in preparing and implementing maintenance activities, saving human resources, material and spare parts, quick reduction of weak points, reduction of nonconforming products, increasing of the reliability of production equipment, etc. Everything can be achieved on condition that the IS has been correctly selected (user-friendly, open to changes, but also stable, etc.), successfully implemented (the implementation phase is very important full support of top management and effective involvement of all interested personnel) and appropriately used. [3]

MMIS electronically supports arrangement of a number of documents (related to operation) – asset inventory, chronological record of machine maintenance, work orders, a stock numbers of spare parts, a chronological records of parameters, production plans and schedules, chronological records of activities of workers, etc. [6] The basic prerequisite for using MMIS is proper records about maintained objects (based on the "asset inventory"), which is connected to the planning and keeping track of maintenance activities with linkage to the consumption of inventory during maintenance. Following additional sources of information (maintenance personnel availability, equipment and tools disposability, the cost of maintenance, failure codes,

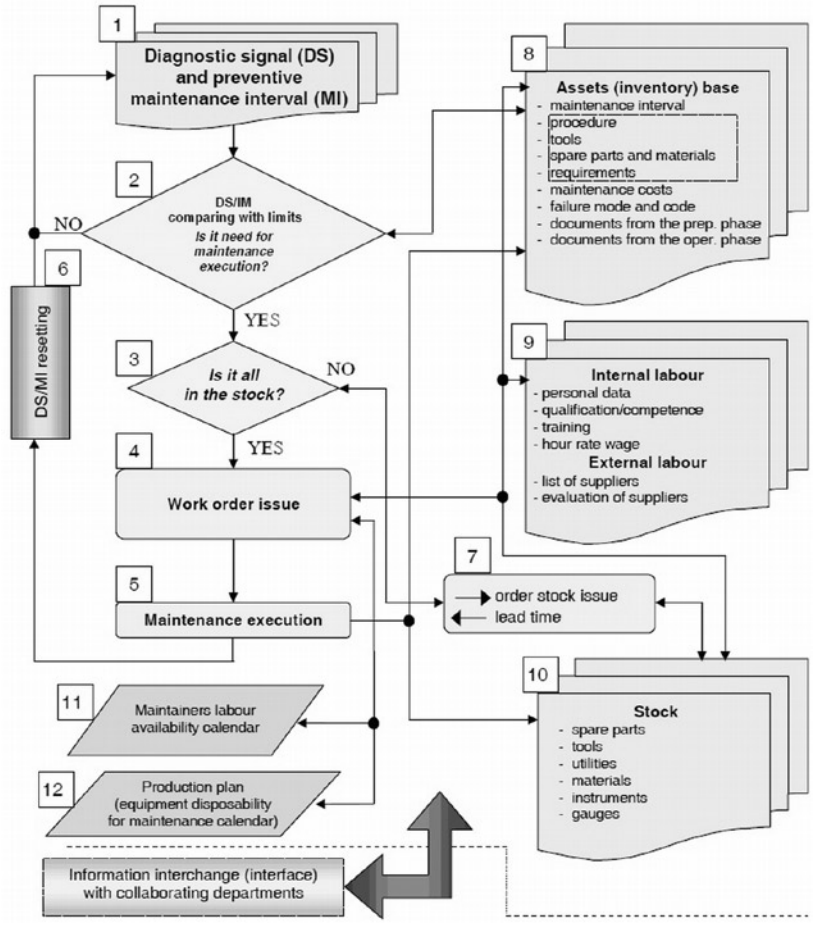

Fig. 1. Simplified MMIS flowchart of preventive maintenance

maintenance requirements, etc.) are recorded in long-planned and unplanned maintenance - their causes, labor, downtime, cost, etc. The maintenance data are commonly used for planning and various operational analysis of maintenance system - for example, to identify costs, labor intensity and duration of downtime of the selected object within selected period in order to determine the monthly maintenance costs for individual departments or production lines, to monitor the failure of machinery and eliminate frequent causes of failures, to summarize the maintenance personnel labor worked each year, etc. Knowing the theoretical bases of appropriate procedures (with recorded maintenance data), it is possible to obtain a number of other indicators that can significantly help in planning, assessment, and thus the continuous improvement of maintenance. Simplified MMIS diagram of preventive maintenance management in industries is shown in Figure 1.

Even agricultural company can use the same principle of MMIS, if the selection and implementation of MMIS will be done with respect of agricultural specifics versus industrial.

3. Results and discussion

Although it seems at first sight that maintenance systems in industrial and agricultural companies are very different, in fact they are not. Apparent obstacles using MMIS in agricultural companies exist in other sectors too, but these obstacles do not hinder using of MMIS - such as seasonal work exists in the sugar-houses, where the MMIS is used, as well weather conditions apply to construction companies, etc. The main causes of lower distribution of the maintenance management system in general and its computer support in agricultural companies are mainly these:

- In the Czech Republic there are relatively few large agricultural companies which could effectively use MMIS.
- Affordable, yet high-quality applications of MMIS appeared just recently on the market in the Republic
- Agricultural companies still do not appreciate the positive aspects of well-functioned maintenance system – similar situation was apparent in the industrial companies 15 years ago
- Lack of software and hardware facilities in the agricultural companies causes poor data communication among their divisions and also between agricultural companies and companies providing the maintenance outsourcing
- For complex machineries the maintenance is outsourced through dealers of specific brand and maintenance system is entirely managed by the dealer; for simple machineries maintenance after the failure is usually applied by own workers, often unskilled
- Lack of companies offering outsourced maintenance of agricultural machineries without a narrow link on a specific manufacturer or supplier of agricultural machinery.

However, it is possible to assume that in the up-coming years MMIS will be extended to larger agricultural companies. Some dealers of farm machinery have been working on applications that will ensure efficient flow of data within a communication channel dealer (repair service company) – agricultural company. These applications enclose evidence, planning and managing of maintenance activities, etc. Density of the service networks of suppliers of agricultural machinery is already sufficient, and it is still constantly growing. Agricultural companies (which use MMIS) and dealers of agricultural machinery are together connected via the corporate Web applications on a central server with data store and access to knowledge bases, spare part inventories, etc.

Effective maintenance systems should be based on collaboration and data link at least the level of largest suppliers of agricultural machineries in the Czech Republic with individual agricultural companies. Consolidated information system should share necessary data for maintenance management of particular agricultural companies, evidence of maintenance history and plans of preventive maintenance etc.

However, this solution is not an option because of concerns about misuse of enterprise data shared by cooperating companies. These concerns are often completely unnecessary, information technology allows access to data configuration for participating users, but in practice it is clear that sometimes claustrophobic fears about misuse of data will not be overcome in the near future.

A. Traditional in-house maintenance system

This model could be functional identically as in industry, where using the MMIS system of maintenance procedures is managed without relationship to the external environment and various maintenance subcontractors (outsourcing maintenance). Maintenance carried out by own workers are registered and MMIS planed essentially in the same way as outsourced maintenance. Maintenance system setting, the continuous monitoring and optimization of efficiency is controlled by the maintenance manager of agricultural company. This model is already running in several agricultural companies in the Czech Republic, but its disadvantage is the need to duplicate records of major machineries, for which maintenance is provided by external companies (usually dealers of the brand that have delivered machinery) who are also interested to record maintenance activities. By recording maintenance data on the same machinery in two different information systems often leads to errors due to human error, and quite often, the dealer has different data than the agricultural company. Agricultural companies are not usually equipped with devices for collecting diagnostic signals (which have dealers). Such a fact results in situation that agricultural companies do not have relevant and valuable information about the technical state of machinery - particularly for predicting the evolution of the technical condition of the machine and thus the need of future preventive maintenance.

B. Shared maintenance system

This system has the advantage that it eliminates the major insufficiencies of traditional in-house maintenance system. Agricultural company and dealer work together with the data collected on a single server, the MMIS set rights for individual users for access to input and view data. Unlike the previous model, the maintenance manager of the agricultural company could analyze the output of diagnostic device from dealer. On the other hand, the dealer should have a detailed overview of the planned maintenance which provides for the agricultural company, failure of machines, the need for spare parts, etc. The great advantage of this model is that if the planned maintenance in the MMIS is approved, both interested partners can prepare in advance. Affordable MMIS also includes failure monitoring module, so if a requirement is entered into MMIS by agricultural company, it immediately informs the dealer and the failure may be quickly removed. Even it is useful for both sides, described model is not spread in agricultural sector (minor share of this model in industry). This model is facing the above-mentioned reluctance to share data among partners.

C. Outsourcing of maintenance of agricultural machinery

Like in the industry, also in agriculture it is possible to expect the establishing of specialized companies for the maintenance of various agricultural machines. These companies could completely ensure the maintenance of machinery for agricultural companies by supply method. All data collected during maintenance of agricultural machinery would be owned and maintained by MMIS in outsourcing company. Using of MMIS would be in the interest of outsourcing company for easy planning of preventive maintenances and analysis capabilities of maintenances and also in order to increase its effectiveness. This model is typically used in the industry (chemical industry, heating plants, electric grids, etc.), but it has disadvantage, which is complicated communication in terms of dates of scheduled maintenance activities, and as well recovery of operational failures. There

Table 1. List of machinery and their average age and average downtime costs per hour

Machinery	Number of machinery	Average age in year 2010 (years)	Number of machinery		Average downtime costs per hour (CZK)
			In-house maintenance	Dealer's maintenance	
Tractors	28	12	13	12	900
Stubble ploughs	5	8	5	0	3 500
Ploughs	8	7	6	2	4 800
Machinery for soil cultivation before planting	22	14	22	0	3 400
Swing machinery	8	8	6	2	6 400
Machinery for fertilizing and crop protection	16	11	13	3	4 100
Harvesters + adapters	6	6	1	5	10 500
Forage machinery	21	7	16	5	3 850
Trucks	14	8	9	5	2 800
Sum, average	128	10	91	34	4 472

is a direct result of the absence of feedback dealers, and agricultural equipment manufacturers, for whom data of the maintenance of their machines during the life cycle is valuable informational basis for further development.

3.1. An example of usage of the MMIS to improve the quality of maintenance in agricultural company

The following example shows the benefits of implementation and subsequent maintenance improvement of agricultural machinery in a particular agricultural company. The company manages 3106 ha (7675 acres), has 112 employees, basic information about its machine park are listed in Table 1.

By the year 2003 (the maintenance was carried out without any system) the majority was corrective maintenance. Preventive maintenance including motor oil changes in mobile machines were made in a subjective decision of machine operator, maintenance documentation was not recorded. In 2004 a new management introduced system measures to improve the quality of maintenance of machinery for crop production. Initially the plan was to set up the proper planning of preventive maintenance and star to record maintenance activities. At the end of 2004, company acquired information system for maintenance management which began routinely used since 2005 but so far without sharing information with dealers of agricultural machines. Sharing information maintenance system with dealers for selected machines began to be applied from the beginning of 2009.

Already at the beginning of the implementation of MMIS in 2004, there were established criteria for assessing the effectiveness of maintenance. Furthermore, new indicators of efficiency maintenance were set up and their numerical values collected from 2005 to 2010 are listed in Table 2. Although there are indicators of maintenance efficiency commonly used in industrial plants, such as Overall Equipment Efficiency, however, these indicators can not be used in primary agricultural production. The newly proposed indicators are based on the requirements for an efficient maintenance system, which is expected to increase the dependability of machines and secondary factors namely availability (also durability and safety), maintenance supportability, while reducing costs of maintenance. When increasing the dependability can be expected less machine failures and thereby reduce downtime, maintenance costs of the failure and the cost of spare parts. When higher dependability is ensured, it can be expected less machine failures and thereby reduction of downtime, costs of corrective maintenance and costs of spare parts.

Additional commentary for the Table 2:

1. Direct annual cost of maintenance (obtained from MMIS) are calculated as a multiple of maintenance workload (intensity) and the maintenance man-hour rate, cost of used spare parts and maintenance material consumed is added to final amount of cost. Trend of direct annual costs of maintenance are shown in the Table 2 (row 1). Subdivisions of direct annual cost of maintenance are presented in rows 2-4.

Table 2. Evaluated indicators of maintenance effectiveness during the year 2005 to 2010

Item	Year					
	2005	2006	2007	2008	2009	2010
Direct annual maintenance cost (thousand CZK)	3 792	3 712	3 423	3 118	2 821	2 593
Cost of corrective maintenance (thousand CZK)	3 356	2 918	2 456	2 378	2 023	1 897
Cost of preventive maintenance (thousand CZK)	436	852	849	740	798	789
Cost of spare parts (thousand CZK)	2 156	2 351	1 860	1 721	1 693	1 456
Number of failures (-)	233	278	238	219	215	194
Downtimes caused by failure:						
Downtimes (hour)	552	499	481	452	406	302
Downtimes recounted on costs (thousand CZK)	2 469	2 232	2 151	2 021	1 816	1 351
Average cost of a corrective maintenance (thousand CZK)	14,40	10,50	10,32	10,86	9,41	9,78
Average length of a downtime caused by corrective maintenance (hour)	2,37	1,79	2,02	2,06	1,89	1,56
Recounted maintenance cost (thousand CZK)	6 261	5 944	5 574	5 139	4 637	3 944

2. The cost of corrective maintenance (obtained from MMIS) is the sum of all costs of maintenance in a given year (all maintenance performed because of failure of any machine).
3. The cost of preventive maintenance can be expressed as the sum of the costs of all preventive maintenance in a given year.
4. The cost of spare parts can be expressed as the sum of costs of all spare parts consumed during maintenance in a particular year.
5. Fifth row shows the number of failures per year, which were solved within maintenance activities. This indicator by itself is not conclusive, because it is not clear whether certain failure was a "big" (laborious, expensive) or "small". In this case, although the number of failures after 6 years has not fallen too much (from 233 to 194), but number of "big" failures was significantly reduced - this is evident in the development of the indicators listed in other rows of the table.
6. Downtimes due to failures are shown in other rows. They are given in hours and also recalculated to the cost of downtime.
7. Downtimes due to failures in hours - are expressed as the sum of downtime caused by corrective maintenance (obtained from MMIS).
8. Downtimes from the previous row are converted to costs by multiplying the average cost of an hour of downtime of the machine (these are shown in the last column of Table 1).
9. Average cost of corrective maintenance is obtained by dividing the total cost of corrective maintenance (row 2) by the number of failures per year (row 5).
10. Average downtime of corrective maintenance is obtained by dividing the total sum of downtime hours of corrective maintenance (row 2) by the number of failures per year (row 5).
11. Costs of downtimes of corrective maintenance are included in the annual cost of maintenance. Annual maintenance costs are calculated as the sum of direct maintenance costs (row 1) and the cost of downtime (row 8).

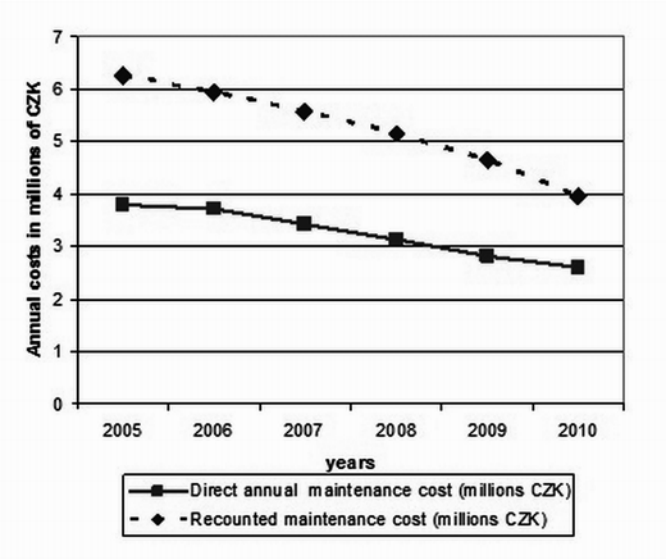

Fig. 2. Trend of direct and re-calculated annual maintenance costs

The trend of the indicators listed in the Table 2 shows that the implementation of a system with MMIS support can significantly reduce maintenance costs while increasing dependability of maintained machines. Especially the emphasis on preventive maintenance which is performed properly makes the biggest benefit of this system. Figure 2 shows that the direct costs for maintenance decreased by more than 1 million CZK per year (32%). Furthermore, re-calculated costs were even lowered by 2 million CZK (36%) during 6 years when all the data were tracked.

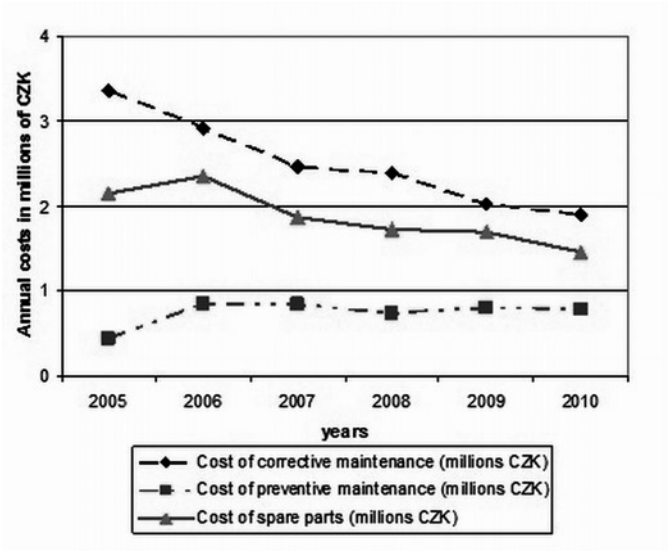

Fig. 3. Trend of subdivisions of direct annual maintenance costs

The trend of subdivisions of the direct maintenance costs (Fig. 3) is evident in each phase of improvements of the maintenance system. The cost of preventive maintenance after increasing of the intensity of preventive maintenance in 2006 abruptly doubled, the slight increase in 2009 is due to the implementation of preventive maintenance carried by dealer (year 2010 compared to year 2005: 172%). The increase of the cost of spare parts in 2006 is due to increased intensity of preventive maintenance and increase of quality of corrective maintenance, while their decline in 2010 was caused due to their lower purchase prices from dealer who performed certain maintenance (year 2010 compared to year 2005: 68%). The cost of corrective maintenance in 2006 and 2007 declined sharply due to the introduction of preventive maintenance in 2005, further decrease was more evident in 2009 after the dealer started to maintain more complex machinery (year 2010 compared to year 2005: 57%).

Improving the quality of the maintenance system with support of MMIS shared with the dealer is evident on the indicators in rows 9 and 10 in Table 2 - the average cost of corrective maintenance decreased by 32%, the average downtime for maintenance after a failure by 30%. It is obvious that although the number of failures decreased only by 17% in 2010, failures are less severe than in the year 2005.

In addition, MMIS and long-stored data about performed maintenance allow analysis of weak points on maintenance system – search of multiple failures and their elimination and possible change of spare parts suppliers with higher frequency failures, changes in schedules of post-season and pre-season maintenance based on the causes of failures, optimizing intervals of preventive maintenance etc.

5. Conclusion

Effective maintenance management in any sector must necessarily be supported by an information system that provides the necessary data for decision making based on real facts. MMIS are increasingly used to manage maintenance systems in the companies. Ten years ago use of MMIS was rather exceptional. MMIS was used scarcely only in industrial enterprises, are now it is almost the rule. Managers of these companies understand that properly implemented maintenance system is another source for the company to reduce costs, and that without the computer aided support the whole company can not achieve effective outcomes. MMIS are increasingly being used in larger agricultural companies in the Czech Republic, where using of

the traditional model of in-house maintenance system poses problems for outsourced maintenance of agricultural machinery dealers. In the following years, it is possible to assume that there will be closer cooperation between dealers and agricultural companies and expansion of a shared maintenance system of MMIS. Shared MMIS in the Czech Republic is still used in only a few agricultural companies. Nevertheless, as it is shown in the example, it is possible to reduce significantly costs while increasing dependability of agricultural machinery.

References

1. Eti M C, Ogaji S O T, Probert S D. Reducing the cost of preventive maintenance (PM) through adopting a proactive reliability-focused culture, Applied Energy 83 2006; p. 1235–1248.
2. Jurca V, Ales Z. Maintenance Management Efficiency Evaluation. Eksploatacja i Niezawodnosc – Maintenance and Reliability, 2007; 33(1); 13-19.
3. Kans M. An approach for determining the requirements of computerised maintenance management systems. COMPUTERS IN INDUSTRY. 2008; 59, p. 32-40.
4. Legat V, et al. Contribution to optimization of preventive replacement. Reliability Engineering and System Safety 51, Elsevier Science Limited, 1996; ISSN 0951-8320.
5. Michel H, Mufeed A. Improving industrial process safety & availability, Reliability Engineering 2008; p. 1021–1026.
6. Westerkamp T A. Maintaining maintenance - How smart managers plan and execute successful CMMS implementations. INDUSTRIAL ENGINEER. 2006; 38, p. 37-42.
7. Wiest W. Improvement of the availability through quality control and preventive maintenance of self propelled vehicles. In: Conference on Agricultural Engineering, VDI BERICHTE vol. 1449, Germany: 1998; p. 351-356.

Prof. Ing. Vladimir JURCA, C.Sc.
Czech University of Life Sciences Prague, Faculty of Engineering
Department for Quality and Dependability of Machines
Kamycka 129, 165 21 Prague – Suchdol, Czech Republic
E-mail: jurca@tf.czu.cz

Ing. Zdenek ALES, Ph.D.
Czech University of Life Sciences Prague, Faculty of Engineering
Department for Quality and Dependability of Machines
Kamycka 129, 165 21 Prague – Suchdol, Czech Republic
E-mail: ales@tf.czu.cz