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Improvement Maintenance Processes through CMMS System
—Case study

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***Abstract*—Computerized systems supporting maintenance management have been successfully applied in many industries. Over time, these systems have undergone significant transformations. When implemented, these systems allow optimization in the areas of: stockholding, parts and materials management, procurement, external services and maintenance and repair work, which contributes to the economic effects of the enterprise. This paper presents the benefits of implementing one of the CMMS modules benefiting from RFID technology in a medical device manufacturer.**

Keywords-maintenance management; CMMS; RFID

I. INTRODUCTION

Nowadays, it is difficult to imagine a modern manufacturing company or an industrial plant without a well-organized maintenance department [1, 2]. Maintenance services are integrated into all the production processes and execute and are responsible not only for maintaining the highest level of availability of machinery, equipment and installations, but also for cost optimization [3, 4], resource efficiency [5, 6, 7] and compliance with social standards [8]. The use of computerized maintenance systems for modern production is indispensable for the efficient management and assessment of maintenance processes [9, 10, 11, 12].

CMMS stands for Computerized Maintenance Management Systems and refers to solutions that are specialized IT systems designed to support broadly defined Maintenance in both small and large manufacturing companies. CMMS support equipment management, inspections planning and maintenance, as well as managing supervisory procedures and service documentation. Their tasks include recording of events related to the production and measurement equipment maintenance, e.g. all types of failures, repairs or inspections, as well as management of maintenance personnel.

This paper describes the application of RFID technology together with CMMS to a medical device manufacturing company. The article is composed of five chapters. After a brief introduction (Chapter 1), the issues related to the support of the IT maintenance system have been characterized. The next chapter describes RFID technology. Chapter 4 is a case study, which describes how one of the CMMS modules functions with RFID, and outlines the benefits the implementation has brought to the company. Chapter 5 is a summary.

II. MAINTENANCE MANAGEMENT ISSUES

The need for having high production equipment availability causes companies to need a more effective and efficient maintenance management system in order to reach a competitive production system. According to the European Standards (EN 13306:2010) maintenance management are all the activities of the management that determine the maintenance objectives or priorities, strategies, and responsibilities and implement them by means such as maintenance planning, maintenance control and supervision, and several improving methods including economic aspects in the organization.

Many industries today face the challenge of managing their maintenance resources as efficiently and cost effectively as possible. The opportunely coordination of different resources like personnel, spare parts, equipment, tools is the key factor to success [13, 14]. A web-based online computerized maintenance management system (CMMS) is a good option to allow field engineers accessing CMMS via local network and internet. Computerized Maintenance Management Systems have a long tradition in many industries. In fact, CMMS are among the first historical steps of maintenance information systems. The main objective of a CMMS is to provide a tool to analyse maintenance and equipment information in order to optimize the management and support for strategic, tactical and

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operational decisions. According to [15, 16, 17], CMMS can provide these items: support condition based monitoring, track the movement of spare parts, allow operators to report faults faster, improve the communication between operations and maintenance personnel, historical information necessary for developing PM schedules, provide maintenance managers with information to have better control on their departments, etc.

Maintenance engineers need access to their work anytime and anywhere, both in connected areas and places without internet. CMMS mobile maintenance supports engineers, technicians and other maintenance department employees in executing their daily work efficiently. Engineers can use their mobile device or smart phones to select their next job, read specific work instructions, query asset-specific information, capture time and materials used and complete a job. A crucial aspect of maintenance management for its various decisions depends on the availability of relevant, good quality as well as timely data that is captured by the ICTs. Hence, radio-frequency identification (RFID) is rapidly emerging as the replacement for the barcode [18]. It can be combined with CMMS to establish a high speed, accurate and reliable wireless maintenance environment.

III. RFID – State of Art

According to Roy Want in [19], "Radio Frequency Identification Technology (RFID) has moved from obscurity into main stream applications that help speed the handling of manufactured goods and materials". This technology has emerged as Frederick Hertz found existence of radio frequency during his experiment in 1886 and developed for the purpose of defense during the Second World War. However, most of the scholars report that the first commercialization of RFID technology was done by Wal-Mart as they launched RFID based material identifying system in 2005 (Table 1).

TABLE I. A Brief History of RFID Technology [20]

Time	Event
1886	The idea of using Radio Frequency to reflect waves from objects was started from Frederick Hertz's experiment.
1930-1940	American navy research laboratories developed a system known as IFF (Identify Friend or Foe).
1940-1950	The first application of RFID consisted of identifying allied or enemy planes during WW2 through the use of IFF system
1973	Charles Walton, a former IBM researcher registered patent using RFID technology, a radio-operated door lock
1980-1990	Many US and European companies started to manufacture RFID tags.
2003	The Auto-ID center for MIT became EPC global, an organization whose objective is to promote the use and adoption of RFID technology
2005	Wal-Mart launched and RFID pilot

RFID is the wireless technology which uses radiofrequency electromagnetic fields to gather data about a certain object without coming in contact with the data carrier. A radio frequency identification system includes three key components:

- a transponder (a word combining transmit and respond - RFID tags);
- a transceiver unit (a read-write device with integrated antenna - RFID readers);
- integration with servers and service and enterprise resource planning systems - RFID middleware).

Tag is a microchip to store the information of the object being tracked and this information is accessed via radio signal of RFID reader/transceiver. To allow wireless transmission of data to the reader tag consists of an antenna which is tuned to receive radio frequency waves emitted by a reader or transceiver. To acquire information from a tag, a reader must send a signal to the RFID tag, triggering the tag to transmit the information to the reader. The reader then reads the signal, converts it to a digital format, displays this information on a built-in screen or transmits it to a linked computer for data analysis and processing. RFID tags can be active, passive, or semi-passive tags, and are classified into five classes according to their capabilities and functionalities. The second key component is RFID reader. These emit low-powered RF signal to activate passive tags; identifying tags; and transferring in formation to and from a tag. here are a variety of RFID readers available on the market. USB and serial port type readers are usually used in PC system; otherwise, CF, SDIO and Bluetooth are selected for PDA's or mobile computers. Besides, RFID readers tend to be embedded into laptops, PDA's, cell phones and other embedded devices.

The next key component is RFID middleware. Middleware refers to software or device that makes the connectivity between the RFID readers that read the data and the enterprise data base systems and is responsible for the quality, and therefore usability of the data. RFID middleware applies filtering; formatting and logic to tag data captured by a reader, and sends this processed data to backend applications. Therefore, middleware applications are needed to manage the flow of data from readers and send them to backend management systems.

In industrial environments, RFID provides the highest value in situations when traceability through a process or item life cycle is required, where labor costs or data errors related to identification and handling are high, when there are time or labor constraints related to item identification, handling or replenishment, and any time business processes or software applications need more information about an object than bar codes or other forms of automated data capture technology provide [21, 22]. In maintenance management two key factors are driving the adoption of RFID [23]:

- Maintenance drivers (e.g. in transparency of maintenance processes, lack of information to determine a proper maintenance strategy, maintenance costs) and
- Information technology innovations (e.g. mobile terminals, tablet computers, wireless communication, component miniaturization, embedded systems with sensors).

RFID can be combined with CMMS to establish a high speed, accurate and reliable wireless maintenance environment. Additionally, RFID contains embedded memory and supports updating of storage information. Based on that, maintenance managers can immediately and accurately identify items, manipulate storage information, such as machinery data, sensor identification, audit trails of maintenance activities, spare part information and use of maintenance tools. By extending the concept to industrial maintenance domain, the integration of RFID with current mobile, wireless and internet technologies can effectively facilitate maintenance operations.

IV. Case Study

A. Charakterystyka System QMS SUR

Thanks to the cooperation with large companies and scientific centers, CMMS system "QMS SUR" was designed and developed by ITM Softare (www.itm-soft.pl). The software is designed as a SUR platform with multiple modules for exchanging and managing information. The software is deployed taking into account the business model of the enterprise and scaled for use in departments and multi-departmental work. Modular construction of the system enables individual adaptation to the needs of a particular organization, as well as later system expansion and integration with already existing IT systems. One of the most recently shared modules for customers is the "Surveillance and Coordination System" (SNKP) (fig. 1).

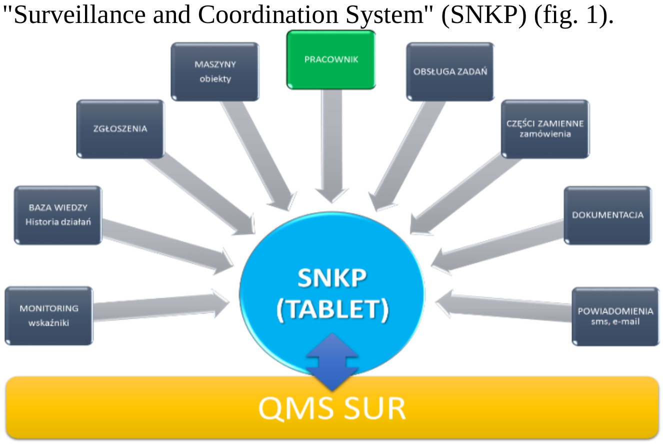

Figure 1. Elements of SNKP module.

The main tasks of the modules are:

1. Assigning Maintenance employee to table 1.
2. Assigning job to the tablet (failure, inspection, maintenance...)
3. Reading the RFID code from the machine (starting and stopping the machine by the operator (start / stop))
4. Job identification (machine - employee) with spare parts necessary to perform the service (issue the part from the warehouse, return parts to the warehouse by reading bar code of the parts)
5. Job identification (machine-employee) with tools necessary to perform the service (tool issuing, tool return, tool bar code reading)
6. Displaying a list of partial tasks, such as inspection, maintenance, lubrication
7. Approving the list of partial tasks
8. Displaying summary information for the task (planned working time, effective working time % of work progress, expected completion time)
9. Localization of the task on the plant map (especially important in large multi-departmental enterprises)
10. Reports for Maintenance coordinator: tasks map, tasks monitoring, employee load, shift reports, data sets to be passed between shifts

Industrial tablets (such as MobiPad P110, MobiPad H9) with RFID readers were used for such a wide range of tasks.

B. Implementation of the Module

The SNKP module was implemented by ITM-Software (www.itm-soft.pl) to medical device manufacturer in January 2016.

Activities implemented by the module can be characterized in general by means of the functional model (Figure 2) and in detail by means of the activity sequences (Table 1)

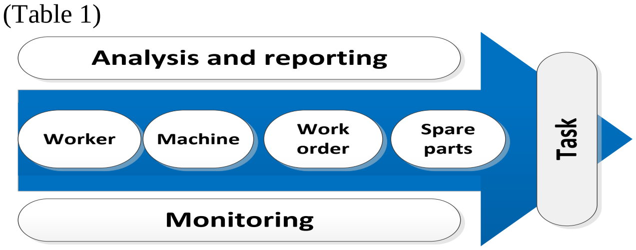

Figure 2. Functional model

TABLE II. Activities Sequences

No.	Sequence
1	employee → task → technical object
2	task → spare parts → tools
3	task → indicators → monitoring
4	raporting → decision (responsible party)

SEQUENCE I: employee -> task -> object

Starting a shift, maintenance employee logs into QMS SUR on the tablet using his RFID card (RCP card – working time recording). From then on, all tasks performed with the tablet will simultaneously identify the employee who performs the task. Other employees may be assigned to the same tablet, but their status is defined as an "assistant". Tasks or elements of the task (so called partial tasks) performed by the assistant will be identified separately in his task account.

From the to-do list, the employee can: Select a task himself or the task is assigned to him by the coordinator, the employee can have multiple assignments - to skip to the next task he has to complete the current task or to pause the task.

The task begins by reading the RFID code of the machine (object) assigned to the task. The employee should read the machine's RFID code each time the job is started and after the job is over - it is important to calculate the actual machine operating time indicators. The Maintenance employee describes the partial tasks to be accomplished on the tablet, for example: "Replacing the tensioning strap of the delivery mechanism" (additional element is taking pictures – it facilitates work of the employee taking over the task).

The system verifies the availability of parts in the warehouse and, in their absence, generates the requisition documents and sends them to the purchasing department, setting a new launch date or monitoring status for that task: if the spare part information appears in the purchasing department (eg.: Planned delivery time or delivery to the warehouse document), it sends relevant information. For selected machines, partial tasks must be approved by the coordinator (depends on machine type and sub-tasks). It is the same as assigning an additional employee to the task - the coordinator approves it. When the system receives information about the failure, the system analyzes the maintenance tasks or inspections planned for the machine for the time being. The system adds additional tasks such as inspection and / or maintenance to the list. Whether or not additional tasks will be included in the implementation, the coordinator will always consult with the production department by sending an email or a text message. If the tasks to be implemented do not have a fixed deadline or it is unknown at the time of commencement of work, the coordinator sends the information to the production department (e-mail) about the need to change the production plans, and after completion of the task confirms its execution to the production department by e-mail.

SEQUENCE II: task -> spare parts or task -> tools

During the task, the Maintenance employee gets (or passes) the spare parts needed to complete the task. In the warehouse, warehouse employee gets information on the task to be executed and with the tablet of Maintenance employee gets parts assigning them to the task. At the same time, data is transferred to the warehouse management module where a new issuing document (new task) is generated or data is added to an existing document, when additional parts are required to perform the task. The warehouse document is validated at the end of a task or in specific cases at the end of a settlement period (eg end of a month). In case of a mistake or return of the spare part to the warehouse, the documents are appropriately corrected. The same routine is for the tools needed to complete the task: the toolmaker assigns the tool to the Maintenance employee using his tablet, the next step is the same as for the spare parts.

SEQUENCE III: task execution -> indicators -> monitoring

Completion of individual tasks is confirmed by Maintenance employee. The system continuously calculates selected indicators, eg: planned repair time, actual repair time, repair costs, estimated start cost due to downtime (Figure 3).

Figure 3. Analytics module.

Locations of individual machines and production facilities in each department were mapped in the system. Thanks to this, managers have the ability to visualize all tasks: executed, paused, scheduled, etc. (Figure 4).

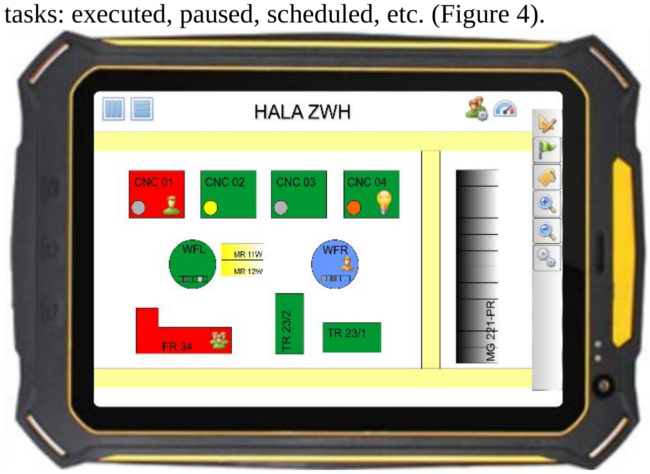

Figure 4. Map of the maintenance tasks.

Thanks to this, the coordinator (as well as the selected employees: managers, planners, etc.) have an on-line view of the service provided and, in case of an emergency, they can manage the assignment of tasks to the appropriate staff. The system updates (with SMS, e-mail) predefined groups of users with tasks, delays, problems (no spare parts) and the completion of work.

SEQUENCE IV: reporting

The system generates on-the-fly reports: per shift, periodic, analytical and calculates indicators such as MTTF, MTBR, OEE for individual machines, cells, departments. Thanks to such information it is possible to dynamically assess the effectiveness and efficiency of technical services, which will result in better decisions taken in the future.

The descriptions of the phases of the SNKP module operation are only to a small extent related to RFID technology. However, using this technology in this module is essential. It allows for simple and effective identification of services, their executors and the resources needed to perform the service (spare parts, tools), which in many cases cannot be replaced by other technologies such as bar codes. Thanks to RFID identification, Maintenance employee does not need to enter the codes for: operator, object, employee, etc. manually. These actions are performed automatically by the system, which firstly saves time, secondly eliminates potential errors.

By comparing historical data for 2015 and 2016, the following effects were found:

1) *Increase in efficiency of Maintenance employees:*

a) *Implementation of tasks was accelerated by 23% and time of completion of documents was shortened by 34%*

b) *87% of the errors related to identifying and classifying data were eliminated*

c) *29% of the actual execution time has been saved*

d) *Based on the above data, 215 corrective actions have been implemented to improve the performance of Maintenance services and optimize resources: reducing overtime by 46% (Figure 5), increasing the rate of tasks completed by the end of the shift by 30%*

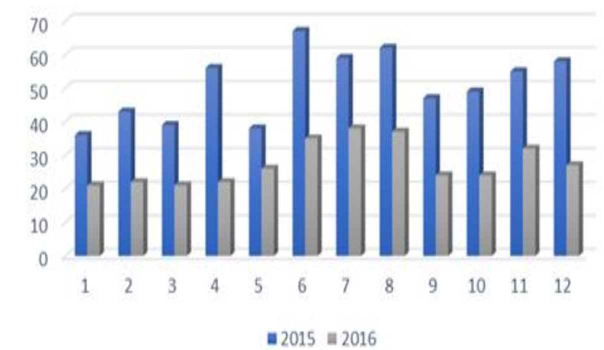

Figure 5. Overtime hours in 2015 and 2016.

2) *The automation of tasks resulted in tangible benefits in accounting for maintenance tasks:*

a) *Better values of MTTR, MTBR, MTBF*

b) *The number of properly filled documents increased: in 2015 there were 1121 discrepancies in employee-filled documents, while in 2016 only 113 (based on document recording data)*

c) *Spare parts replacement time has been reduced (on average): in 2015 the average result was 4 days 3h, and in 2016 the average result was 1 day 1h (Figure 6)*

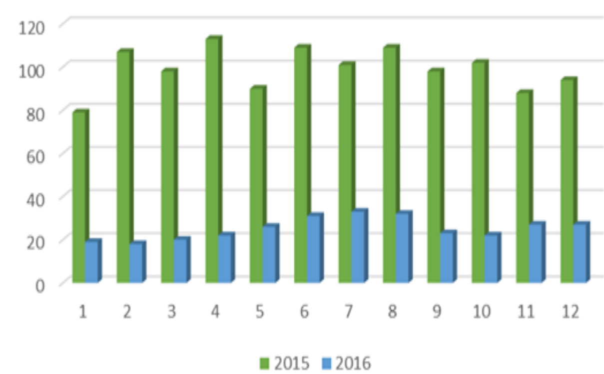

Figure 6. Averange waiting time for spare parts [h].

3) *The results of tasks monitoring ware:*

a) *A drop in customer orders delays by 46% (thanks to the information provided to the planning and production department about tasks that allow for changes in production plans)*

b) *An increase in the level of implementation of the preventive action plan (maintenance and review) by 24% resulted in a 27% reduction in failure rate - mainly through coordination of tasks with the production and planning department (Figure 7)*

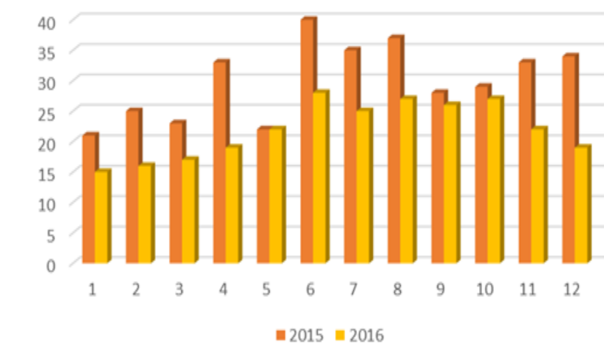

Figure 7. Number of failures in 2015 and 2016

c) *Average reduction by 19% in failure recovery through optimal use of human resources and on-line access to information (especially data on repair history).*

d) *"Knowledge base" was built - all information sent to the system is properly cataloged and classified. This allows access to information on previous failures and other events to be more precise, for example: the operator can view data about previous causes and actions on a given machine, or analyze data from similar requests (for cause, machine groups, damaged part, ...)*

All of the aforementioned effects were certainly not solely due to the use of RFID codes, but this technology has made a great contribution to achieving such effects, and the cost of its use only promotes the benefits that it has achieved.

V. Conclusion

Today, the word "maintenance" becomes a bit insufficient to express what can be done to guarantee the reliability, availability, quality and safety of industrial enterprise infrastructure, both technically and from an organizational point of view. The impact of sustainability issues on maintenance, the total cost of operating technical facilities, new ICT tools to support maintenance, legal aspects, and security implications are some of the challenges to consider and address in terms of maintenance. RFID systems show a great potential for improvement of processes and the reduction of costs associated with maintenance.

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