SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2024
ORGANIZATION AND MANAGEMENT SERIES NO. 210

IMPLEMENTATION OF A CMMS CLASS SYSTEM FOR THE SUPPORT OF MAINTENANCE SERVICES IN ACCORDANCE WITH THE TPM PARADIGM IN A SELECTED MANUFACTURING ENTERPRISE

Julia JURASIK[1], Jan KAŹMIERCZAK[2]*, Łukasz JANKOWSKI[3], Vasyl DMYTRIV[4]

[1] Silesian University of Technology; zj72@onet.pl, ORCID: 0000-0003-4833-5240
[2] Silesian University of Technology; jan.kazmierczak@polsl.pl, ORCID: 0000-0002-2459-470X
[3] no data
[4] Department of Design Machine and Automotive Engineering, Lviv Polytechnic National University, Ukraine; vasyl.t.dmytriv@lpnu.ua, ORCID: 0000-0001-9361-6418
* Correspondence author

Purpose: The paper presents the basic assumptions and the plan of the research work, which is directed at implementing a CMMS class system in a selected manufacturing enterprise to support selected maintenance tasks.
Design/methodology/approach: The research conducted at the company was based on participant observation, using social research techniques and a tool from the Root Cause Analysis group.
Findings: The analysis and diagnosis results were used to develop proposals for implementing a system to support maintenance and repair tasks in selected segments of the production system. These proposals included tool and organizational solutions to increase the efficiency and effectiveness of maintenance activities.
Research limitations/implications: While the issue of maintenance is a key component of manufacturing engineering, the article does not address other equally important areas, such as process design, optimization or quality control, which, with an integrated approach to manufacturing engineering, could lead to synergistic results.
Practical implications: The introduction of solutions based on the TPM paradigm will make it possible to systematically increase the stability of the production process by improving maintenance processes and reducing the risk and severity of the consequences of downtime and failures.
Originality/value: The paper's novelty is its systematic approach, which provides a practical framework for implementing a CMMS in a manufacturing environment. The diagnostic process and the resulting proposals for using the system to support maintenance and repair tasks in selected segments of the production system represent a form of process innovation. The paper is aimed at manufacturing companies seeking to improve maintenance operations and increase productivity by implementing modern management systems.
Keywords: TPM, CMMS, RCA, Lean Maintenance.
Category of the paper: Research paper.

1. Introduction

In today's globalized and highly turbulent industrial environment, maintaining production continuity is undoubtedly a fundamental condition for ensuring the competitiveness of any enterprise. In their search for effective productivity enhancers, companies are beginning to view peripheral tasks such as maintenance of machinery and equipment no longer simply as a technical necessity but also as a strategic source of savings. Undoubtedly, the reliability of production machinery directly affects a company's productivity (Wiśniewska, 2021, pp. 18-19). Still, it is worth considering the random nature of the timing of faults and failures of technical means. Frequent failures and downtime of the machinery fleet result in a reduction in the number of finished goods and, consequently, a reduction in the company's bottom line. For this reason, among the critical tasks of manufacturing enterprises should be ensuring the uninterrupted operation of the machinery park (Drożyner, 2017, p. 31; Ohno, 2008, p. 22; Stroller, 2015, p. 49). Significant costs resulting from unplanned equipment downtime and related repairs justify the increased interest of researchers and practitioners in machinery maintenance aimed at optimizing the operation of manufacturing entities. Taking up the subject of implementing the TPM paradigm, which is one of the methods derived from the Lean Management philosophy (Antosz, 2019, p. 37; Jasiulewicz-Kaczmarek, Mazurkiewicz, Wyczółkowski, 2023, p. 47), is due to the growing importance of this strategy in the Polish industrial environment. The label of Lean remains relevant and eagerly taken up in the manufacturing literature. At the same time, issues related to implementing TPM assumptions are relatively rarely addressed, indicating the need to fill this cognitive gap and undertake research on this topic.

2. Determinants of the choice of research subject

The enterprise, which is the subject of the research that forms the basis of this work, has oriented its activities to the production of locking systems - locks and hinges. The company offers a diverse range of locks and locking systems in various models and with multiple functions, to most effectively meet the dynamically changing needs of the market. A rich assortment of products is linked to the diversity of technology dedicated to its production and, therefore, to the machinery park, which in the context of maintenance means a diversity of maintenance procedures tailored to the specifics of individual machines and equipment. Since the company's management did not agree to this, the name of the company under study will not be used in this study.

In the course of the research described in this paper, it was found, first of all, that the studied enterprise does not implement a conscious maintenance management strategy (Antosz, 2019, p. 23; Bartochowska, Ferenc, 2014, p. 11) and does not use terminology specific to this area. However, it has been observed that, as it were, unconsciously, the Run To Failure strategy of machine operation, i.e. use until failure or symptoms of failure appear, is used in the surveyed company (Antosz, 2019, pp. 23-24; Fidali, 2020, p. 19; Jasiulewicz-Kaczmarek et al., 2023, p. 22; Werbińska-Wojciechowska, 2018, p. 20), supplemented by cyclic, though not very frequent, reviews (Kazmierczak, 2000, p. 21; Vanderschueren et al., 2023). In doing so, there is no analysis of effectiveness (Fidali, 2020, p. 14; Kosicka, Mazurkiewicz, 2015, p. 78), nor are the far-reaching effects of doing so analyzed.

3. Identification of disturbances in the operation of machinery and equipment

In the course of conducting participatory observation in the technical department of the company under study, the regular occurrence of incidents such as breakdowns and malfunctions of production machinery and equipment, resulting in the downtime of certain segments of the production line, was observed. In order to obtain a detailed picture of the situation, the 5W2H method was applied (Fig. 1). This revealed that the people most frequently encountering the defined problems are the production line operators and customers, who, as a consequence of production downtime, complain about the untimely fulfillment of their orders. These incidents occur almost daily, and each machine malfunction causes interruptions in the production process, increasing operating costs and the risk of losing customers to more operative competitors. It was found that in a period of less than eight months, nearly 677 hours were spent repairing equipment at the surveyed company, causing minor or major production disruptions.

It was noted, however, that the disturbances reported by the operators were only a superficial symptom of deeper-rooted problems which, to better understand them, were analyzed using a methodology known as Root Cause Analysis (RCA). A fault tree diagram (Fig. 2) was drawn up, based on the 5WHY technique (Stroller, 2015, p. 70), which involves asking successive "why?" questions until the root causes of the situation under investigation are identified.

1. WHO? Who detected the problem?
Production line operators and customers.

2. WHAT? What constitutes the problem? What happens when it occurs?
Prolonged production process downtime due to failures.

3. WHEN? When does the problem occur?
Almost every working day.

4. WHERE? Where does the problem appear?
On the production line.

5. WHY? Why is this situation a problem?
Every minute of machine downtime prevents the continuation of production.

6. HOW? What are the causes of the situation, and how can they be eliminated?
The current situation may have multifaceted causes.

7. HOW MANY? What is the scale of the problem? How much time does the problem consume?
The company under study spent nearly 677 hours on repairs of its production equipment in less than eight months.

Figure 1. An example of using the 5W2H method to describe the problem.

Source: Own elaboration.

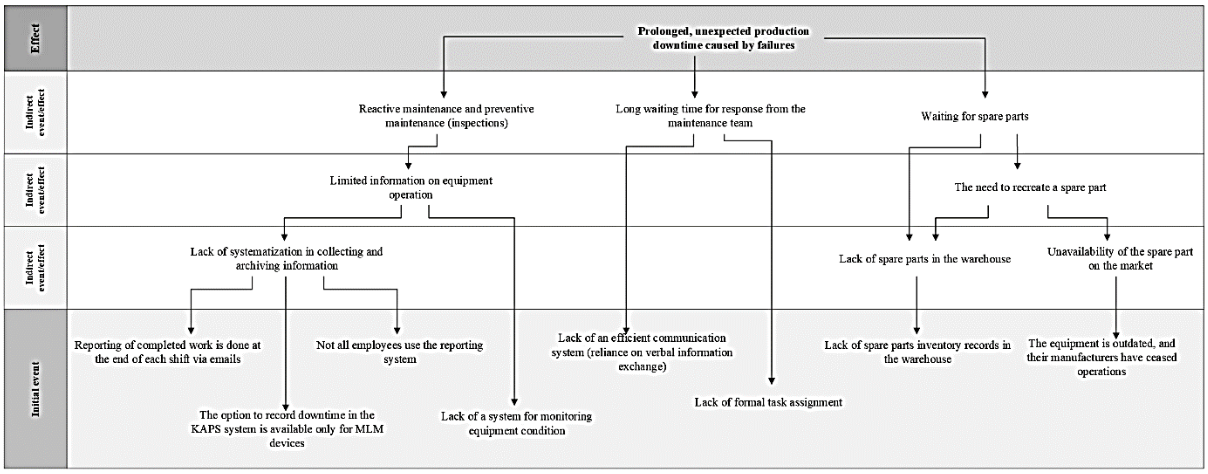

Figure 2: Fault tree diagram.

Source: Own elaboration

It was thus concluded that the maintenance system at the company under study operates in a reactive mode due to the lack of sufficient information based on the operation of machinery and, thus, the ability to recognize symptoms of impending failures. The lack of systematic monitoring of residual processes causes failures to occur unexpectedly. In addition, the verbal transmission of information delays maintenance services' reaction to the incident. The operator of a malfunctioning machine is forced to personally go to the UR department to notify service technicians or find them on the production floor. The existing form of reporting needs to be a sufficient source of data to describe the comprehensive history of machine operation. Not all incidents are recorded in the proprietary ERP system, the KAPS system currently used at the company under study. Information about the repair work carried out on a given day by UR employees is forwarded via email to the head of the technical department. It can also be noted that employees could be more precise in describing the objects of their work in their reports, and the time spent on repairs is determined post-factum, leading to inaccuracies. In addition, materials and parts used during repairs are rarely indicated, which is key data for effective analysis of the cost of work performed and maintenance of machines. On the other hand, in warehouse management, a lack of record-keeping of received and issued spare parts was detected, which often leads to shortages and prolonged repair times as a result of waiting for the delivery of the missing component. These problems show a strong correlation, so the search for solutions was directed at finding a comprehensive solution, eliminating the sources of the mentioned disruptions, to improve the functioning of various areas of the organization, especially in managing fixed assets and human resources.

4. Implement improvements in maintenance management.

Based on the diagnosed disruptions and the results obtained using an interview questionnaire conducted among technical department employees, machine operators, and forepersons employed at the surveyed enterprise, the maintenance management needs of this enterprise were defined. These needs include scheduling inspections and maintenance, monitoring the condition of production equipment, recording all maintenance events, including failures and defects, and queuing maintenance events based on task priorities. In addition, it is necessary to calculate performance indicators for UR services, inspect the scope of work performed by these services, formalize and standardize reports on maintenance activities, archive information on work performed, and document repair history. It is also essential to record the retrieval and receipt of spare parts in the warehouse and to communicate information about their shortages to the engineering team, as well as to speed up the circulation of information about adverse events between operators and mechanics. Starting from such a list of needs, the objectives of implementing improvements in the maintenance system were detailed, which include reducing the waiting time for repairs and the duration of the repairs themselves, putting spare parts management in order, and ensuring an adequate level of availability of spare parts, and improving communication within the technical department and between the technical department and the production department.

The assumptions of the TPM concept, due to their focus on failure prevention, increasing availability, and maximizing the productivity of company assets, are an appropriate solution to the problems identified in the operation of the technical department of the studied enterprise. Before the implementation of the comprehensive maintenance strategy, pre-implementation work was carried out, during which the following was done: identification of the stakeholders of the UR system in the selected enterprise, identification of the requirements and objectives concerning the implementation of improvements within the management of maintenance activities, determination of the inputs and outputs of the process of implementing the TPM concept, and how to measure the degree of fulfilment of the requirements (Drożyner, 2017, p. 70). It has been stated that, following the philosophy of Lean Management (LM), the implementation process should involve employees at all levels in the organization's hierarchy, with a particular focus on the employees of the technical department and the supervisors and operators of the production department along with the management of both departments (Lalitha, Rahmawati, 2020, p. 29; Legutko, 2009, pp. 11-13; Musa et al., 2015, pp. 165-166). In addition, it is advisable to include an external stakeholder who could act as an impartial coordinator of the implementation work.

Table 1.
Model service card

SERVICE CARD		
Device:		
Purpose/scope of service work:		
Responsible person:		
Date and time of commencement of service work:		
Actions performed:		
Tools used:		
Spare parts/consumables used:	Spare part/consumable:	Quantity:
Additional insights:		
Date and time of completion of service work:		
Signature of the performer:		

Source: Own elaboration.

Further research revealed deficiencies in the necessary documentation. The following were drawn up to fill them: a list of tangible assets (machinery and equipment) to be covered by the new management system and a list of standard spare parts used in the listed production machinery. Because within the technical department of the company under study, there is practically no coherent system of collecting information on operating events, enabling them to be archived, a model for such a document in the form of a paper service card was proposed (Table 1).

The content of the charter was developed in accordance with the 4W1H method. MRT, MTR, MTTR, MTBF, and MTTF indicators were selected to verify the effectiveness of maintenance activities (Antosz, 2019, pp. 49-50; Daniewski, Kosicka, Mazurkiewicz, 2018, p. 22; Janisz, Liszka, 2018, pp. 516-517). Having the proper foundations of the new system, they proceeded to implement the next pillars of the TPM paradigm. The work began with the implementation of the principles of the 5S method. The 5S initiative can be seen as the foundation of the TPM philosophy (Bartochowska, Ferenc, 2014, p. 17). Keeping the workplace tidy expands the availability of space needed for maintenance tasks. Maintaining cleanliness, especially in the workshop area of maintenance and repair services, reduces the time spent locating the tools needed to fix faults and breakdowns, reducing machine downtime. It has been proposed that the contents of tool cart drawers be organized using appropriate inserts and trays, power tools should be placed on labeled storage bays in tool cabinets, and the remaining tools should be deployed on a perforated board. To standardize the cleaning procedure, simple checklist-type document templates were prepared to facilitate the restoration of order in the tool room (Table 2).

Table 2.
Example of 5S instructions for a tool room

5S MANUAL FOR THE TOOL STORAGE		
1	Wipe and remove dirt from the worktop	
2	Place parts and tools in dedicated storage areas	
3	Make sure that there are no empty spaces in the recesses of the storage areas of the trolley drawers	
4	Make sure that the instruments in the cabinet are located in dedicated, described places	
5	Collect all rubbish, waste and other unnecessary items. Place them in dedicated buckets	

Source: Own elaboration.

As part of the autonomization of maintenance tasks, it has been proposed to equip operators with preventive maintenance cards (Table 1), describing cleaning procedures for different groups of production equipment (Musa et al., 2015, p. 167) and, in line with the Kaizen idea, cards for recording disturbing events (Table 3), used to document symptoms of malfunctioning machinery.

The incident history compiled this way forms the basis for implementing a predictive strategy. Analysis of inspection results can be used to identify patterns and trends in machine problems. These proposed tables align with the Kaizen culture, in which listening to employee suggestions is promoted. By integrating existing preventive measures with the results of analyzing symptoms recorded by operators in event cards, it becomes possible to prevent waste by performing preventive maintenance, adjustments, repairs or replacements of parts on still-functioning machines.

Table 3.
Model card for recording worrying events/symptoms

Disturbing event/symptom		Date	Time
1			
2			
3			
. . .			
n			

Source: Own elaboration.

In implementing the quality pillar, it was proposed to place quality tables at each production line station, containing visualizations of the desired patterns and unacceptable defects of finished products. The implementation of an autonomous maintenance and prevention system should contribute to improving the quality of UR services by reducing the number of failures. A cause-and-effect sequence can be observed here: reducing the number of failures slows down the rate of wear and tear of machines. It improves their service life, and the proper technical condition of equipment ensures that machine interference does not reduce the quality of the products produced on them.

As part of the safety pillar (OSH), the surveyed company has put in place several safeguards to ensure worker safety within the shop floor, reducing the number of operator absences caused by accidents during work. The program to protect workers includes proper marking of dangerous machine components, particularly on presses, and installation of guards and light barriers on machines, as well as the deployment of cabinets for storing personal protective equipment such as safety glasses and earmuffs and marking of traffic routes divided into pedestrian routes and forklift zones. In addition, a three-module training program on maintaining the TPM pillars was prepared to familiarize stakeholders with the company's current changes. By closely linking the pillars of TPM, the holistic implementation of the concept generates synergy, in which strengthening one area brings benefits to the others, creating a coherent system of operational improvement.

The "TPM in the office" pillar is designed to arrange activities to improve communication within the company, particularly between the technical department and production. The main objective set for this pillar is to reduce the service response time to a technical request. This requires the introduction of uniform communication tools for the personnel of both departments and the development of standard procedures and communication channels for different types of information (Pinto et al., 2020). The most appropriate and effective solution for smoothing the flow of information in the enterprise is the introduction of integrated IT maintenance process management systems for monitoring and coordinating UR work. An example of such a system is CMMS-type software.

5. Implementation of software to support the pillars of the TPM paradigm

During the operation of a machine/equipment, various data can be acquired, including operating time, descriptions of observed faults and failures, descriptions of repair activities performed, lists of used parts and consumables, and recorded parameters of machine/equipment operation. Such data is a crucial component of the "operation management system" - Maintenance Management System. Due to the abundance of such data, manual collection, recording, and processing of such data becomes inefficient, ineffective, and, in many cases (especially for very complex technical systems), even unfeasible. This makes it particularly difficult to respond appropriately and promptly to operational incidents. Therefore, more and more often, maintenance management systems use advanced IT technologies and take the form referred to by the term Computerized Maintenance Management Systems (CMMS) (Jasinski, 2019, pp. 25-26; Jasiulewicz-Kaczmarek, 2023, p. 136). When implementing TPM assumptions, a CMMS is considered optional but strongly recommended. Simply implementing a CMMS does not guarantee an immediate solution to maintenance problems. However, it can be a beneficial tool, provided it is properly implemented, and its available functionalities are adequately used (Östberg, Nilsson, 2016, p. 24). The selection of a CMMS class system suitable for a particular enterprise should be based primarily on an analysis of the individual needs of that enterprise, considering the possibility of selecting and adapting to these needs and capabilities of the system-chosen modules in the implementation procedure. Successful implementation of a CMMS can reduce maintenance costs, improve communication within the enterprise, and increase the availability of machinery and equipment, so enterprises seeking to optimize maintenance processes should consider its implementation.

Computerized enterprise resource management systems, especially CMMS class software, are also tools that can help solve the problems of disorganization in the technical department of the selected entity.

Let's assume that in the past, the entity used traditional, "analogue" methods of maintenance management, which proved to be time-consuming, error-prone, and hindered rapid response to adverse events. Digitization of the maintenance management area could allow for more effective supervision and coordination of maintenance work, centralizing data and information on this enterprise area. A CMMS-type system would provide a consistent platform for planning, supervising, and reporting maintenance activities at the operational and tactical levels. It is essential to make the use of the system available not only to maintenance mechanics, those directly responsible for maintenance work, or technical department employees overseeing the effectiveness of maintenance processes but also to forepersons and operators so that the system can provide a common platform of communication for all parties involved.

Before starting the implementation process, it is necessary to find a suitable system capable of responding to the challenges and needs posed by a given manufacturing entity. During the search for and implementation of a suitable CMMS system, the research described in this paper used a needs satisfaction process model consisting of the following steps:

1. Identify the company's needs and expectations of the system's capabilities.
2. Define criteria for evaluating available systems.
3. Detailed analysis of IT solutions available in the market.
4. Evaluation and selection of the most suitable system.
5. Implementation and testing of the selected system.

Having identified the company's needs concerning the CMMS system, the research described here assumed that the CMMS system to be implemented would have a modular structure. A set of requirements was then defined for the available modules, such as maintenance scheduling, warehouse management, and call handling. Attention was paid to such aspects as the availability of a Polish-language version and a mobile application, the legibility of the interface, and subjective ease of use.

Price is also a value that should be considered in the selection process when evaluating a CMMS system. Nevertheless, it is worth emphasizing that the choice of a system should not depend solely on its cost. In practice, investing more money often ensures obtaining a system that meets high standards, especially in terms of reliability of operation and availability of updates.

Out of nearly thirty CMMS systems available on the Polish market, nine possibilities were selected and evaluated in terms of defined requirements. Based on the requirements collected in the interview questionnaire, areas were determined, which were then analyzed in the nine selected CMMS class systems. Comparative analyses were made based on information obtained during meetings and consultations with sales representatives of the manufacturers of the chosen systems, as well as subjective impressions made while learning about the functionality of the tools. The evaluation was conducted on a 5-point scale: one means not meeting the company's expectations, and five means fully meeting the requirements. It was noted that the selected systems have similar functionalities, while they are distinguished by the way they present information and the accessibility of the appearance of the application interface.

According to the analysis, it was suggested that the QRmaint® system be used at the surveyed enterprise, guided in particular by the low entry threshold and minimal implementation requirements. Due to the incompatibility of data collected in the company's previously used "proprietary" KAPS system with the data format of the selected CMMS system, all data and information had to be transferred manually. The data transfer to the CMMS system was divided into tasks for an organized and systematic approach to the process, ensuring that all relevant information was entered into it.

Critical steps in the process include:

1. Compile personal data of system stakeholders:
   a) preparation of user profiles, including personal data, qualifications held, and individual QR codes to facilitate log-in,
   b) collecting data on external service providers - determining their competence and assigning contact information,
   c) collecting data on regular suppliers of spare parts: this will allow you to determine which components a particular supplier is responsible for supplying and assign them up-to-date contact information.

2 Transfer previously collected documentation and prevention plans into the system:
   a) digitizing the map of the machinery park for the departments covered by the change,
   b) mapping of production equipment with assigned technical specifications, past maintenance schedule, checklists for maintenance, historical data of work performed, and incidents recorded, based on information entered in the former system and collected through service cards, standard list of spare parts,

c) giving the machines QR codes,
d) transfer of the existing schedule of infrastructure reviews,
e) enter the power tools located in the workshop and assign QR codes to them,
f) digitizing inventories, preparing places for replenishing necessary standard parts, and assigning QR codes for items, suppliers, specified security, and maximum levels.

In the implemented system, based on the list of production machines and equipment to be covered by the system, the structure of the machinery park was mapped, assigning individual machines to appropriate departments and positions. Thanks to this, when a failure is reported, or a planned preventive action is about to be carried out, the zones and equipment affected by the events are made visible in conjunction with the ANDON light paging system. In addition, the notification or report received by the relevant employee shows the previously mapped location, speeding up the process of finding the location of the problem.

The preventive plans available to the enterprise have been entered into the "Preventive Tasks" module. The list of preventive work presented is also a schedule for this work. The review time is defined once in the system, which then automatically renews the task in the schedule and generates notifications, with an assumed time advance, about the approach of the scheduled activity.

Thanks to its inventory of standard spare parts and its stock inventory, the implementation described here envisaged the creation of a digital warehouse of spare parts for production machinery and equipment. The collected data was transferred to the warehouse module of the CMMS system: photographs of the parts, their names, purchase costs, and quantities held were entered, minimum and maximum stock levels were defined for each item, and information was entered on which machines the part is dedicated to. In addition, each group of parts was given a unique QR code, which, when placed in the appropriate storage location, allows for a significant acceleration of picking and receiving into the warehouse.

It was recommended that the storage cabinet space be organized and a signature system be introduced so that each part can be assigned a location on a specific shelf, drawer, tray, or container. Releases from the warehouse will be recorded automatically when the use of parts during maintenance activities is approved. When a part's stock exceeds the minimum state, the system will generate a notification addressed to the engineering team and include a suggestion to replenish the stock to prevent a shortage of the desired parts during future interventions.

Screens have been installed in the production halls and the UR services office to increase accessibility to information. These screens display dashboards showing critical operational performance indicators and information on operating events. They also allow production employees to track the status of requests made, which promotes greater process transparency and commitment to the tasks at hand. In addition, compiling information on a single, large screen makes it easier for maintenance mechanics to spot a problem immediately.

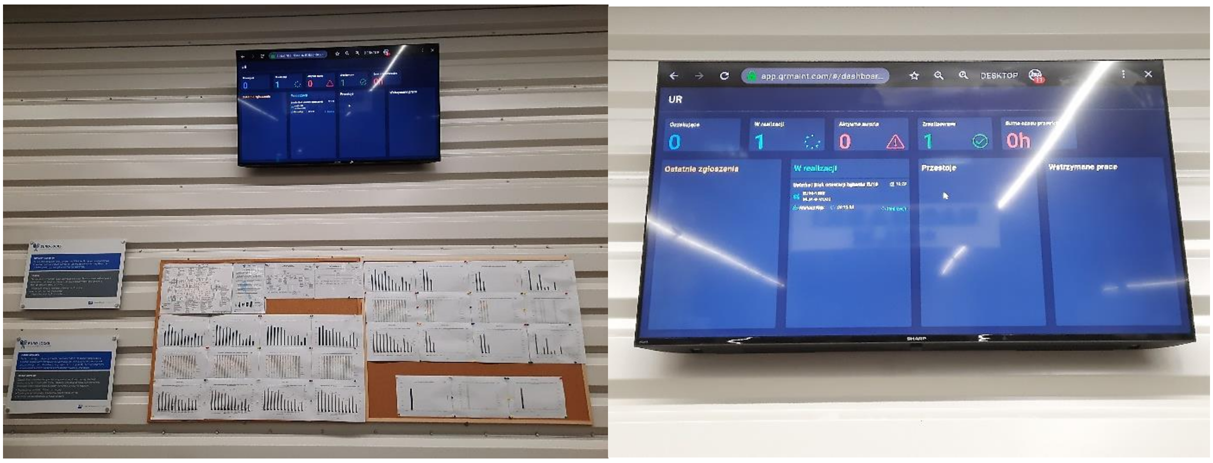

Figure 3. An example of a dashboard in the studied enterprise.

Source: Own elaboration.

After implementing the CMMS class system, the process of reporting failures and repairing was significantly transformed by moving the procedures to a virtual plane. According to the "old-fashioned" scenario, operators were obliged to personally report the occurrence of a problem on the production line to the maintenance staff present on a given shift, which often involved a lengthy search for these employees within the production halls. Implementing QR (Quick Response) technology, an essential tool for automating activities in modern maintenance management should bring several benefits at every stage of the maintenance process. Failure notifications, made via a two-dimensional code scan, are immediately transmitted to mechanics via a mobile or computer application and interactive whiteboards, eliminating the oral communication stage. Replacement parts retrieved using the QR code are automatically assigned to the job report, facilitating subsequent cost analysis. Cases of missing parts caused by neglecting to update inventory will be eliminated.

On the other hand, the digitization of documentation summarizing the work performed will eliminate the need for "physical" access to computer workstations with the KAPS system, simplifying the process of completing information and eliminating, for example, skipping reports due to forgetfulness. The basic information in the reports, presented as a checklist, supplemented with a detailed description of the work performed, and a list of parts used, will be a simplified form of the previously proposed service card. Such checklists will function according to the "necessary step" principle of the "PokaYoke" approach (Dudek-Burlikowska, Szewieczek, 2009). Failure to fill in any of the fields will result in disapproval of the report on the request. All data on failures, repairs, and preventive work will also be automatically archived, allowing for later analysis and identification of recurring problems.

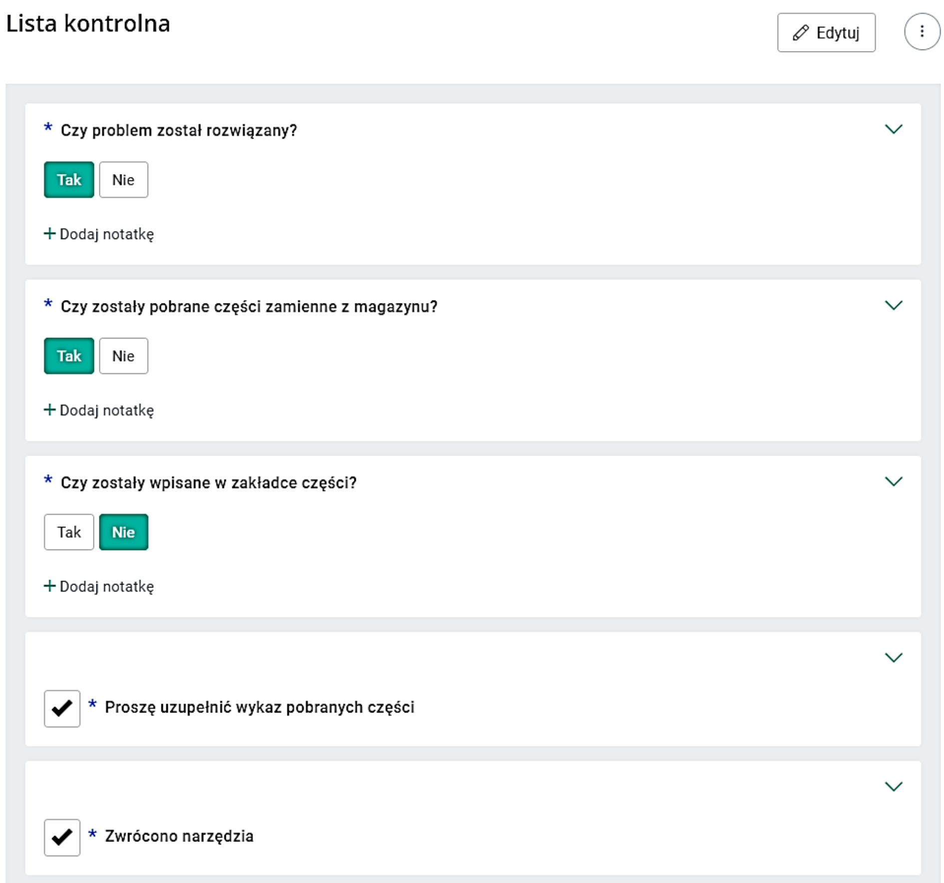

Figure 4. An example of a checklist in a CMMS system.

Source: Own elaboration.

6. Summary

As a result of the research, far-reaching specific conclusions have been formulated that go beyond the results obtained during this research. These conclusions show the expected results that a full implementation of the CMMS system by the TPM paradigm could produce. Attempting to quantify the effects of the implementation presented in the paper is not feasible for several reasons. First, the selected system still needed to be fully implemented: one-month tests of the functions of its demo version were conducted, and such a limited testing period needed longer to collect enough data to make reliable analyses and compare changes in the values of operational efficiency indicators. As a result, the available data need to allow a comprehensive assessment of the long-term impact of the CMMS on the company's operations. However, an attempt has been made to describe the potential long-term benefits of practising the assumptions of a comprehensive productivity maintenance strategy.

The implementation of the pillars of the TPM concept and the CMMS system that supports them will potentially contribute primarily to the elimination of waste, such as:

- disruption of production continuity caused by employee absenteeism due to occupational accidents, thanks to the introduction of elements of the health and safety pillar - guards and light barriers on machines, warning pictograms, marking of transport routes and health and safety cabinets;
- "overproduction" and overprocessing in the form of unnecessary, too-frequent preventive maintenance activities, thanks to a combination of preventive work and predictive elements in the form of applied "alarming event recording cards" (Tab. 3), which consequently allows for condition-based decision-making and prevents unjustified maintenance and replacement of still-functioning parts;
- unutilized potential of employees through the implementation of the AM program, through which operators gained new competencies, thus relieving UR services from performing some tasks;
- corrections of defective products resulting from improper work by operators, thanks to quality boards placed at the stations;
- maintenance services, which were partly eliminated by expanding the competence of operators within AM so that simple work can be performed by production employees, but especially with the implementation of the CMMS system, which has accelerated and streamlined communication between the technical and production departments;
- movement, manifested in situations where the operator is searching for a mechanic when a breakdown occurs, thanks to the implementation of the CMMS system, eliminating verbal information flow;
- unnecessary movement when searching for spare parts and tools in a chaotic warehouse space by applying the principles of the 5S method;
- unnecessary spare parts inventories, but also component shortages, thanks to records of their retrieval and return in the CMMS system;
- production downtime due to damage to machinery and equipment, thanks to the planning and monitoring of maintenance work; all of the factors mentioned above, as well as the other improvement measures introduced under each of the TPM pillars, contributed to the reduction in downtime.

Summarizing both the results obtained and the potential results of further implementation work, it should be stated that the effective implementation in a manufacturing enterprise of an information system supporting the maintenance tasks of machinery and equipment should be regarded as an essential component of comprehensive management of production processes, such as design, optimization, quality control and ensuring the continuity of operation of machinery and equipment. From the point of view of the principles of production engineering, only such a comprehensive approach allows the effective implementation of the entire tasks of a production enterprise.

References

1. Antosz, K. (2019). *Methodology of modeling, evaluation and improvement of Lean Maintenance concepts*. Rzeszów: Oficyna Wydawnicza Politechnika Rzeszowskiej.
2. Bartochowska, D., Ferenc, R. (2014). *Maintenance in small companies*. Łódź: Publishing House of the Technical University of Łódź.
3. Daniewski, K., Kosicka, E., Mazurkiewicz, D. (2018). Analysis of the correctness of determination of the effectiveness of maintenance service actions. *Management and Production Engineering Review, 9(2)*.
4. Drożyner, P. (2017). *Modeling of maintenance processes in an enterprise*. Olsztyn: Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego w Olsztynie.
5. Dudek-Burlikowska, M., Szewieczek, D. (2009). The Poka-Yoke Method as an Improving Quality Tool of Operations in the Process. *Journal of Achievements in Materials and Manufacturing Engineering 36(1)*.
6. Fidali, M. (2020). *Methods of machine and equipment diagnostics in predictive maintenance.* Bielsko-Biała/Katowice: Elamed Media Group.
7. Janisz, K., Liszka, M. (2018). Analysis of machine utilization efficiency on a selected production line. In: R. Knosala (Ed.), *Materials of the IZIP Zakopane 2018 Conference, Volume II, Part XI Maintenance Management*. Opole: Oficyna Wydawnicza Polskie Towarzystwo Zarządzania Produkcją.
8. Jasinski, M. (2019). *Methodology of planning preventive maintenance activities of underground machinery* (Doctoral dissertation, Poznan University of Technology). Poznan: Poznan University of Technology.
9. Jasiulewicz-Kaczmarek, M., Mazurkiewicz, D., Wyczółkowski, R. (2023). *Strategies and methods of maintenance.* Warsaw: PWE.
10. Kazmierczak, J. (2000). *Eksploatacja systemów technicznych dla studentów kierunków zarządzania.* Gliwice: Wydawnictwo Politechniki Śląskiej.
11. Kosicka, E., Mazurkiewicz, D. (2015). Computer support of preventive maintenance processes - a case study. In: A. Swić, J. Stamirowski (eds.), *Modeling and control of manufacturing systems.* Lublin: Lublin University of Technology.
12. Lalitha, B.S., Rahmawati, R. (2020). The empirical study on mediating role of AMT on the TQM and autonomous maintenance implementation in world-class manufacturing. *Qualitative and Quantitative Research Review, 5(3).*
13. Legutko, S. (2009). Trends in the development of maintenance of equipment and machinery. *Operation and Reliability, 2*.
14. Musa, M.A., Kasim, N.I., Razali, A.R., Mahadzir, I., Wan Saidin, W.A.N. (2015). Improvement of Overall Equipment Effectiveness (OEE) through the implementation of autonomous maintenance in crankcase line. *Applied Mechanics and Materials, 761*.

15. Ohno, T. (2008). *Toyota's production system: more than large-scale manufacturing*. Wroclaw: ProdPress.com.
16. Östberg, S., Nilsson, V. (2016). *Determining CMMS needs in an industrial group (Master's thesis, Lund University).* Sweden: Lund University.
17. Pinto, G., Silva, F.J.G., Baptista, A., Fernandes, N.O., Casais, R., Carvalho, C. (2020). TPM implementation and maintenance strategic plan - a case study. *Procedia Manufacturing, 51*.
18. Stoller, J. (2015). *Lean CEO. On the road to excellence*. Warsaw: MT Business.
19. Vanderschueren, T., Boute, R., Verdonck, T., Baesens, B., Verbeke, W. (2023). Optimizing the preventive maintenance frequency with causal machine learning. *International Journal of Production Economics, 258, 108798*.
20. Verbinska-Wojciechowska, S. (2018). *Maintenance models of technical systems in the aspect of the concept of time delays.* Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej.
21. Wisniewska, M. (2021). *Improving production processes using Lean Manufacturing tools*. Włocławek: Publisher of the State Vocational University in Włocławek.