Evaluation of Maintenance Processes in Manufacturing Companies

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ABSTRACT

Digitalization is becoming a crucial factor in enhancing the efficiency of maintenance processes in manufacturing companies. However, many organizations still rely on manual work practices. As a result, problems arise such as the lack of integrated systems, increased likelihood of equipment downtime, and rising operational costs. Redesigning business processes and applying advanced technologies helps minimize disruptions and enables faster and more informed decision-making. Therefore, it is increasingly important to analyze digitalization models and assess their applicability in real operational settings. The aim of this study is to present a digitalization model for maintenance processes in manufacturing companies that would help reduce equipment downtime and improve operational efficiency. To achieve this goal, the following research objectives were formulated: to analyze the types of digitalization models and tools used in manufacturing maintenance processes, to evaluate the implementation potential of a digitalization model through expert assessments and in-depth interviews, and to provide recommendations for improving current maintenance processes based on digitalization principles and empirical findings. The study applied methods such as scientific literature analysis, expert evaluation, in-depth interviews, process analysis, and modeling. The results revealed that standard maintenance processes are largely performed manually, with information transferred verbally or recorded across separate systems, often using Excel spreadsheets or physical logbooks. Such practices increase the risk of errors, slow down information processing, and hinder effective management. The proposed model integrates solutions such as artificial intelligence, Internet of Things (IoT) sensors, and a computerized maintenance management system (CMMS). It is recommended to implement this model gradually, beginning with the most vulnerable process areas such as planning, data recording, and task assignment. A step-by-step transition from the standard to the improved process would enable smoother integration into the company's operations and enhance the efficiency of maintenance processes.

Keywords: maintenance in manufacturing companies, maintenance processes, process management, process reorganization, manufacturing companies.

1. Introduction

In the manufacturing sector, employees' ability to quickly adapt to market changes and technological innovations is becoming an increasingly important factor. According to data from the European Commission (2023), as many as 82 percent of industrial companies indicate that the lack of technological skills is one of the main barriers slowing the progress of digitalization in maintenance processes. Similar trends are also identified in international studies, which emphasize the importance of employees' digital skills in successfully implementing digital solutions in the maintenance processes of manufacturing companies (Aktef et al., 2025). Although more and more companies are investing in digital solutions, maintenance processes in Lithuanian manufacturing companies still remain largely non-automated. Based on data from the Lithuanian Innovation Centre (LIC, 2024), only 14 percent of manufacturing companies have implemented digital maintenance systems, while as many as 63 percent still rely on paper-based work reports, resulting in inefficient and difficult-to-manage processes. The report of the State Data Agency (2024) also highlights the benefits of digitalization: in companies that use digital solutions, productivity per employee reaches an average of 51 thousand euros, while in traditionally operating companies it is only around 32 thousand euros. These figures suggest that implementing digitalization solutions in maintenance processes significantly contributes to improving operational efficiency.

In today's environment of digital transformation, companies increasingly seek ways to improve their business processes to enhance flexibility and performance. In the field of maintenance, it is particularly important to implement solutions that not only help optimize processes but also enable the automation of decision-making (Fasna & Gunatilake, 2019). Improving processes allows companies not only to reduce costs but also to create greater value through the application of digital technologies (Dursun et al., 2022). Studies show that without clear changes in the structure of the processes themselves, the impact of digitalization can remain limited and ineffective (Musonda & Okoro, 2022). Considering this information, it can be stated that the digitalization of maintenance processes in manufacturing companies is one of the most important factors that can significantly improve operational efficiency, ensure sustainability, and strengthen competitiveness both locally and internationally. The core problem of this study is that carrying out maintenance processes without digital tools leads to frequent equipment failures, long repair durations, unplanned downtimes, and increased costs, which may reduce competitiveness by up to 1.5 times (LIC, 2024). International research indicates that non-automated maintenance processes result in an average of 20 percent lower equipment availability compared to companies that have already implemented digital solutions (Buer et al., 2021). Therefore, the object of this research is the maintenance processes in manufacturing companies.

To address this problem, the goal of the study is to present a digitalization model for the maintenance processes in manufacturing companies that would help reduce equipment downtimes and improve the efficiency of equipment operation. To achieve this goal, the following research tasks were formulated: to analyze the types of digitalization models and tools used in maintenance processes in manufacturing companies, to assess the implementation possibilities of the digitalization model based on expert evaluation and in-depth interviews, and to propose suggestions for improving the current maintenance process by applying digitalization principles and empirical research findings. This study employed research methods such as scientific literature analysis, expert evaluation, in-depth interviews, process analysis, and modeling.

2. Literature Review

Manufacturing companies are increasingly aiming to improve their efectiveness (Kourriche et at., 2023) and maintenance processes through digital technologies that support not only real-time information collection but also data-based decision-making. Technologies such as artificial intelligence and sensors enable more precise control of maintenance activities and ensure their systematic execution (Kans, 2023). Digital tools include various solutions such as the application of Internet of Things (IoT) sensors, Computerized Maintenance Management Systems (CMMS), and artificial intelligence (Aktef et al., 2025; Čyras et al., 2024; García et al., 2022; Merkevičius et al., 2024). These tools enable the implementation of preventive and predictive maintenance systems that help avoid unexpected failures (de Azevedo et al., 2023). Artificial intelligence helps to identify process failures in a timely manner and reduces equipment downtime (Patil, 2024), while CMMS systems assist in planning, controlling, and organizing all maintenance-related activities (García et al., 2022). However, organizations still face several challenges when implementing IT tools, such as investment costs, employee resistance, or low levels of digital skills (Venâncio et al., 2023). The scientific literature increasingly explores the importance of Business Process Reengineering (BPR) in the context of digital transformation, particularly in industrial and maintenance sectors. BPR allows organizations to redefine the logic of processes, optimize workflows, and eliminate redundant actions (Wang et al., 2024). Dursun et al. (2022) demonstrated that even in complex sectors such as healthcare, the application of BPR has led to increased efficiency. The success of BPR projects often depends not only on technological factors but also on organizational readiness and change management (Fasna & Gunatilake, 2019). In addition, the application of process modeling and simulation is essential to evaluate the potential effects of changes in advance (Ito et al., 2021). The study by Pasaribu et al. (2021) confirms that well-defined and digitized procedures can significantly enhance process standardization and resource management, even in administrative settings such as higher education institutions. Moreover, the application of BPR facilitates the integration of multiple IT tools, such as CMMS and business intelligence (BI) systems, into a unified digital infrastructure. Furthermore, Martins et al. (2024) highlight that the successful adoption of BI systems plays a key role in enhancing reporting capabilities, which is critical for real-time decision-making and transparency in maintenance operations. This is particularly important, as many organizations face data fragmentation and inefficiencies in decision-making. Finally, research emphasizes that the success of digitalization initiatives depends on how well these solutions are integrated into the overall organizational strategy (Vera & Zapata, 2022). In recent literature, increasing attention is given to the importance of modeling in the context of maintenance process digitalization (García et al., 2022; Patil, 2024; Nasirinejad et al., 2024). A model is described as a logical and structured sequence of actions that helps to analyze, predict, or optimize the impact of digitalization on maintenance operations. Based on the literature, the following types of maintenance models can be identified:

- **Diagnostic model** – used to analyze the current situation and identify process deficiencies, helping companies determine the main problems that limit effectiveness and accuracy (García et al., 2022);
- **Process efficiency improvement model** – aimed at increasing performance, optimizing resource use, and minimizing unnecessary steps (Patil, 2024);
- **Predictive model** – enables artificial intelligence to forecast potential failures or malfunctions in advance, thus ensuring preventive maintenance (Nasirinejad et al., 2024);
- **CMMS integration model** – demonstrates how computerized maintenance systems are embedded within the organization's operations, ensuring process continuity, accountability, and real-time data accessibility (García et al., 2022).

In summary, the digitalization of maintenance processes includes both the automation of data collection and decision-making, with a focus on accuracy, speed, and transparency. Scientific literature has identified the main components of maintenance processes, such as process organization, data collection, the application of IoT and sensors, data analysis and decision-making, failure registration, repair planning, result recording, prioritization of digitalization, and the use of artificial intelligence. Each of these components is associated with specific IT tools, summarized in Table 1 along with their purpose, advantages, and limitations (García et al., 2022; Kans, 2023; Patil, 2024; Venâncio et al., 2023; Nasirinejad et al., 2024; Aktef et al., 2025; Buer et al., 2023; Borowski et al., 2023; Favoretto et al., 2023; de Azevedo et al., 2023; Pasaribu et al., 2021; Martins et al., 2024).

Table 1. Digitalization tools for maintenance processes (compiled by the authors)

Maintenance Process	Digital Tools (IT)	Purpose of the Tool	Advantages	Disadvantages
Process organization	CMMS system	Planning of maintenance and task assignment (García et al., 2022)	More efficient process management, reduced downtime (García et al., 2022)	High implementation cost, training required (Venâncio et al., 2023)

Data collection	Temperature and vibration sensors	Real-time monitoring of equipment condition (Kans, 2023)	Enables timely response to deviations (Kans, 2023)	Requires calibration and system integration (Venâncio et al., 2023)
Use of IoT and sensors	IoT networks, sensors	Centralized data collection (Akter et al., 2025)	Detailed diagnostics, integration with CMMS (Akter et al., 2025)	Security vulnerabilities, investment needs (Buer et al., 2023)
Data analysis and decision-making	AI analysis, data forecasting	Failure prevention using historical data (Patil, 2024)	More accurate decisions, reduced downtime (Patil, 2024)	Requires high-quality data, complex integration (Favoretto et al., 2022)
Failure registration and task generation	CMMS system	Failure logging and automatic task allocation (García et al., 2022)	Fast response, centralized information (García et al., 2022)	System relies on manual data input (Borowski et al., 2021)
Repair planning	CMMS and AI	Optimization of repair time and resource allocation (Nasirinejad et al., 2024)	Reduces repair costs, saves time (Nasirinejad et al., 2024)	May be difficult to align with existing systems (Venâncio et al., 2023)
Results recording and reporting	CMMS reporting modules	Automatic data reporting to management (García et al., 2022)	Clear accountability, transparency (García et al., 2022)	Additional analysis required due to data overload (Borowski et al., 2021)
Digitalization priorities	Strategic planning	Identification of key areas for digital transformation (Buer et al., 2023)	Supports change management, reduces risks (Buer et al., 2023)	Requires leadership and team support (Venâncio et al., 2023)
Application of artificial intelligence	AI algorithms	Failure prevention, process optimization (Patil, 2024)	Reduces downtime by up to 50 percent (Nasirinejad et al., 2024)	High dependence on technical infrastructure (Nasirinejad et al., 2024)

3. Research Methodology

In order to assess the implementation of maintenance process digitalization in manufacturing companies and determine how these tools affect process efficiency, an expert evaluation was conducted. The research was carried out using a semi-structured in-depth interview method combined with a structured questionnaire. According to Mohammadi et al. (2025), proper selection of experts ensures the validity and relevance of the research results. Experts were selected based on two main criteria – relevant qualifications in the field and professional experience. A total of 8 experts participated in the study, each having at least 7 years of experience in maintenance, manufacturing, or digitalization, and all were employed in manufacturing companies. They held managerial or decision-making positions and possessed practical knowledge of implementing IT tools in maintenance processes. The experts were asked questions to determine which IT tools for maintenance process digitalization are most effective in manufacturing companies, what problems they help to solve, and how they contribute to reducing downtime, increasing equipment reliability, and improving overall process efficiency. The questions were grouped according to maintenance processes:

3.1. Process Organization

How are preventive maintenance inspections planned and performed in your company?

Are there specific requirements for the frequency of these inspections?

How often are these processes reviewed or adjusted based on production changes?

What technical or IT tools are used to support planning and implementation?

What are the main advantages and disadvantages of these tools?

3.2. Data Collection

What methods are used to collect data about equipment condition (e.g., vibration, temperature, ultrasound)?

Are automatic sensors used or are measurements taken manually?

How is the data recorded (e.g., on paper, in Excel spreadsheets, in software)?

What IT or technical tools are used for data collection?

What are their main advantages and disadvantages?

3.3. Application of Internet of Things (IoT) and Sensors

Are IoT technologies or sensors used in your company to monitor equipment condition?

If so, what specific data do they collect (e.g., vibration, temperature, pressure)?

How is the collected data integrated into maintenance processes?

Is this data transmitted in real time?

Based on your experience, what are the advantages and disadvantages of these technologies?

3.4. Data Analysis and Decision-Making

What tools are used in your company for analyzing the collected data (e.g., BI, CMMS)?

Is data analysis carried out automatically or manually?

Who makes decisions about equipment operation or repair based on the analysis?

How long does it take from data collection to decision-making?

What are the main advantages and disadvantages of the applied solutions?

3.5. Failure Registration and Task Generation

How are observed equipment failures recorded in your company?

Is specialized software used, or is the recording done manually?

How are repair tasks generated?

How are these tasks delivered to the technicians – electronically, verbally, or on paper?

What are the advantages and disadvantages of these methods?

3.6. Repair Planning

What are the main challenges encountered when planning repair work?

Are they related to lack of information, spare parts availability, or staff scheduling?

How are these challenges addressed in your company?

What technical or IT tools are used for repair planning?

What are the advantages and disadvantages of these tools?

3.7. Result Recording and Reporting

How is completed maintenance work recorded in your company?

Is the data registered manually, or is there an automated system?

How is this data integrated into the company's general reporting system?

What tools are used to prepare maintenance reports for management?

What are the benefits and drawbacks of these solutions?

3.8. Digitalization Priorities

If you could only digitalize certain parts of the maintenance process, which would you choose first and why?

On what basis would the selection be made – existing experience, frequent errors, or performance gaps?

What would be the most anticipated benefits from digitalizing these specific processes?

3.9. Application of Artificial Intelligence

How do you evaluate the potential of applying artificial intelligence (AI) in your company's maintenance processes?

Are you currently implementing or planning to implement AI-based solutions?

If not, what are the main reasons – technological, organizational, financial, or other?

In your opinion, how could AI contribute to reducing downtime, improving planning efficiency, or speeding up decision-making?

4. Research Results

Summarizing the expert evaluation results, the current state of maintenance process digitalization in manufacturing companies and the key challenges faced were identified (Table 2). A detailed expert assessment was conducted using an in-depth interview method – the study involved 8 professionals from different fields with experience in maintenance management, IT implementation, or consulting. The insights provided by the experts helped identify the main issues: processes are often non-automated and carried out manually, there is a lack of integrated systems, and planning and task allocation are frequently based on verbal instructions or Excel spreadsheets. Most experts agreed that the current processes are inefficient and need to be improved by implementing IT solutions – particularly the digitalization of planning, task generation, data collection, and analysis. The importance of CMMS, BI, IoT solutions, and even AI integration was emphasized as having strong potential to improve maintenance efficiency.

Differences in opinions were also observed in expert responses. For example, regarding the application of the Internet of Things (IoT) and the integration of Artificial Intelligence (AI), views diverged – some experts stressed that these remain a distant prospect due to insufficient data or IT infrastructure, while others highlighted that they are already applying these solutions or actively preparing for their implementation.

The data in Table 2 shows that maintenance process digitalization in manufacturing companies is still not sufficiently developed. Most companies still rely on Excel or other basic tools for preventive inspection planning, and only a quarter use CMMS systems. Data collection is most commonly performed manually, while IoT technologies are still either under consideration or applied in a very limited way across most companies.

This highlights a clear need to strengthen digitalization efforts in the areas of process organization, data capture, and sensor integration.

Table 2: Expert evaluation of maintenance process digitalization: process organization, data collection, application of Internet of Things (IoT) and sensors (compiled by the authors)

Process	**Evaluation Aspects**	**Expert Evaluation Results**
Process organization	IT tools for planning preventive inspections, frequency of reviews, advantages and disadvantages	75% of experts indicated that they use tools such as Excel, Google Sheets, Outlook calendars, or SharePoint tables for planning preventive inspections. The other 25% already use CMMS systems, which allow for the automation of planning and adjustments based on real-time data. Review frequency is defined as quarterly, monthly, or as needed. Advantages include accessibility, simplicity, and ease of editing, while the main disadvantages are data fragmentation, the amount of manual work, risk of errors, lack of automatic reminders, and the absence of centralized process tracking.
Data collection	Equipment condition monitoring methods, data recording, IT tools evaluation	70% of experts monitor equipment condition using temperature and pressure gauges, while only about 30% mentioned using vibration, ultrasonic, or IoT sensors. Data is most commonly recorded manually: into Excel, templates, or physical logs. Only a few experts noted that automated data transmission is used to CMMS or Power BI systems. Manual entry dominates due to accessibility but limits analytical possibilities and data comparability. Some experts reported using a hybrid model, where manually and automatically collected data are integrated into reporting systems.

Application of IoT and sensors	Use of IoT sensors, types of data and integration, advantages and disadvantages	50% of experts stated that their companies have not yet implemented IoT technologies but are exploring the possibilities. The remaining 50% mentioned using temperature, pressure, vibration, or load sensors. Collected data is most often integrated into Power BI or CMMS, and in some cases, cloud platforms are used. The main advantages include the ability to automate task generation, reduce human errors, and transition to predictive maintenance. However, key disadvantages were also identified, such as implementation costs, lack of IT infrastructure, data quality challenges, and the need for employee training.

Table 3 presents the results of the expert evaluation, showing that most companies still conduct data analysis using Excel spreadsheets or PDF forms, while only a portion apply advanced solutions such as Power BI or CMMS. Failure registration is typically performed verbally, in logbooks, or on cards, although some companies have started implementing mobile applications that allow automation of this process. Maintenance planning is also often based on incompatible data and verbal coordination, with CMMS solutions used only by a small number of companies. These findings reveal that the digitalization of processes remains limited and that a transition to more integrated and automated IT systems is necessary to ensure more efficient management and reduce the risk of errors.

Table 3: Expert Evaluation of Maintenance Process Digitalization: Data Analysis and Decision-Making, Fault Registration and Task Assignment, Maintenance Planning (compiled by the authors)

Process	**Evaluation Aspects**	**Expert Evaluation Results**
Data Analysis and Decision-Making	Data analysis tools, decision-making, effectiveness of IT solutions	60% of experts indicated that data analysis is still performed using Excel spreadsheets, PDF forms, or verbally during management meetings. Only 40% reported using systems based on Power BI, CMMS, or AI that enable the generation of KPIs, MTBF/MTTR reports, or automated alerts. Decisions are mostly made by managers or engineers based on experience. The effectiveness of IT solutions becomes evident when they are integrated, enabling faster and more objective decisions supported by data. However, main challenges include data quality, lack of systematic analysis, and insufficient data analysis skills among employees.
Fault Registration and Task Assignment	Fault registration and task assignment, applied tools, their evaluation	More than 60% of experts stated that faults in companies are usually reported verbally, in logbooks, on cards, or via Viber. About 40% identified the use of CMMS or mobile applications,

		which allow real-time fault recording and automatic task assignment. Tools mentioned include Excel, SharePoint, CMMS modules, and mobile work orders. Traditional methods are quick but unsystematic and hinder proper data tracking. Digitalized solutions improve transparency and historical tracking but require implementation discipline and employee engagement.
Maintenance Planning	Maintenance planning challenges, used IT tools, their benefits and drawbacks	70% of experts noted that the main challenges in maintenance planning are a lack of spare parts, data inconsistency, employee availability, and unexpected faults. Most commonly used tools include Excel, SharePoint, Outlook, and Google Sheets. 30% of experts reported using CMMS or Power BI solutions. These tools are valued for fast information sharing and flexibility. However, drawbacks were also identified, such as verbal coordination, data fragmentation, lack of automated notifications, and non-integrated inventory information. Digital solutions offer visibility but require habit changes and IT system discipline

Table 4 reveals that the registration of results and reporting in manufacturing companies is still frequently performed manually using Excel or PDF forms. The key priorities for digitalization include automation of task allocation, KPI analysis, and information management, along with the integration of systems such as CMMS, ERP, and BI. Artificial intelligence is evaluated differently, as some companies already apply AI solutions, while others face a lack of technical or human resources. This indicates a strong need to improve data centralization and automation in order to enhance efficiency and support more evidence-based decision making.

Table 4. Expert evaluation of maintenance process digitalization: result registration and reporting, digitalization priorities, application of artificial intelligence (compiled by the authors)

Process	**Evaluation Aspects**	**Expert Evaluation Results**
Result registration and reporting	Recording of results, report generation, level of automation	60% of experts noted that result recording is still done manually using Excel spreadsheets, PDF forms, paper logs, or email. Only 40% mentioned CMMS or Power BI integration, which allows real-time task tracking and automatic report generation. The level of automation remains low in most cases, as reports are often prepared manually using incomplete or outdated data. Digital solutions provide greater visibility and analytical

		capabilities but require employee discipline and ongoing data quality monitoring.
Digitalization priorities	Digitalization priorities and directions, main limitations	75% of experts suggested prioritizing digitalization in task assignment, KPI analysis, inventory and warehouse management, as well as planning. The other 25% emphasized the importance of integrating data into a single system (CMMS, ERP, or BI). Key challenges identified include repetitive manual tasks, fragmented information, frequent verbal communication, and inconsistent data flow. Experts stressed that integration and automation are crucial to improving process efficiency, transparency, and timely decision-making.
Application of artificial intelligence	Possibilities of applying artificial intelligence, obstacles and expert evaluation	50% of experts view artificial intelligence as a promising but currently difficult-to-implement solution due to data shortages, unprepared IT infrastructure, and lack of skills. The other half already apply AI solutions such as anomaly detection, MTBF analysis, Power BI integration, and machine learning. Key obstacles include data quality issues, resistance to change, personal attitudes, and the need for investment. Experts agreed that AI could enhance efficiency and standardize technical maintenance processes if implemented correctly.

Overall, the expert evaluation confirms that maintenance process digitalization in manufacturing companies remains in an early stage. While isolated digital tools are sometimes used for planning, data analysis, or task tracking, full integration across processes is rare. Experts highlighted widespread reliance on manual methods, such as verbal instructions and spreadsheets, and emphasized that fragmented data flows and inconsistent IT usage hinder efficiency. Although some companies are exploring or piloting CMMS, IoT, or AI solutions, broader adoption is limited by infrastructure constraints, insufficient staff training, and organizational inertia. These insights underscore the need for a unified digital strategy to enhance operational transparency, reduce downtime, and support data-driven decision-making.

5. Recommendations for the Process Reorganization for Manufacturing Companies

Based on the analysis of scientific literature, the results of the expert evaluation, and in-depth interviews, the maintenance process within the company was improved. Experts emphasized that the standard process (Figure 1) was inefficient: most actions were performed manually, information was communicated verbally or managed in separate systems, often using Excel spreadsheets or physical logbooks. Such practices increased the risk of errors, created the potential for information loss, and led to the repetition of tasks. Experts identified the need to implement integrated IT solutions that would enable automation and ensure better process control. In the improved process (Figure 2), Artificial Intelligence (AI) and IoT sensors were integrated to collect equipment operation data, such as temperature, vibration, or load. These data are transferred to the AI system, which performs analysis, forecasts potential failures, and, upon identification, sends information to the Computerized Maintenance Management System (CMMS). The system automatically checks whether the required spare parts are available in stock and, if not, initiates a procurement order. A maintenance schedule is then created, and the work results are entered into the system and used for reporting. These improvements help reduce manual workload, accelerate information flow, minimize the likelihood of errors, and support real-time, data-driven decision-making. This contributes to reducing equipment downtime and improving operational efficiency.

Figure 1 illustrates the standard maintenance process model, which was assessed as inefficient due to the frequent use of manual actions. The process includes initiating diagnostics, measuring vibration, temperature, and ultrasound, conducting a physical inspection of the equipment, analyzing data, making decisions, recording failures, and planning repairs. In this model, information is often communicated verbally, tasks are not systematically managed, and data are recorded in various formats or logbooks. This process resulted in a higher risk of errors, limited traceability, and delayed responses to technical failures. For these reasons, experts emphasized the need to transition to an automated, digitally driven solution.

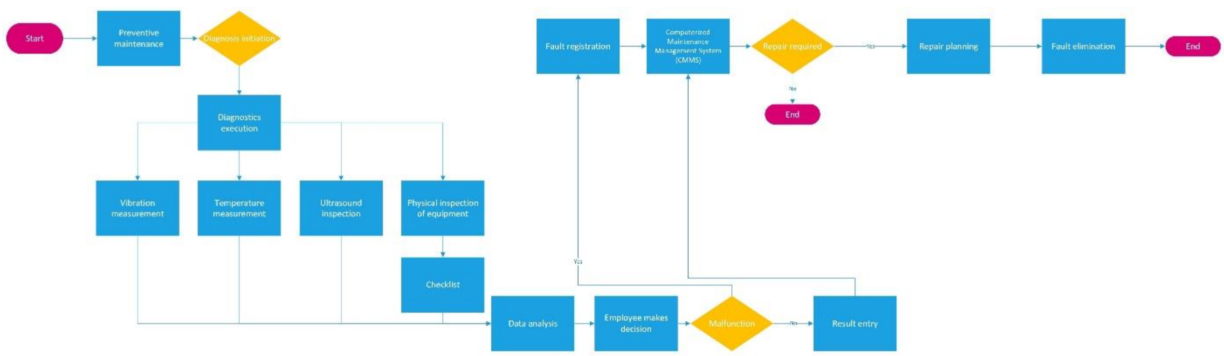

Figure 1: Standard maintenance process model (compiled by the authors)

Figure 2 illustrates the improved model of the maintenance process digitalization, which integrates advanced IT solutions, artificial intelligence, and Internet of Things (IoT) sensors. In this process, data about equipment condition (temperature, vibration, and load) is collected automatically using sensors that transmit the information to an AI system for analysis and failure prediction. Once a fault is identified, the data is transferred to the Computerized Maintenance Management System (CMMS), which automatically checks spare part availability and initiates an order if needed. A repair schedule is then created, and data about completed tasks is automatically transferred to the system for analysis and report generation. This model helps reduce human error, improves data accuracy, enables real-time decision-making, and ensures more efficient management of the entire maintenance process.

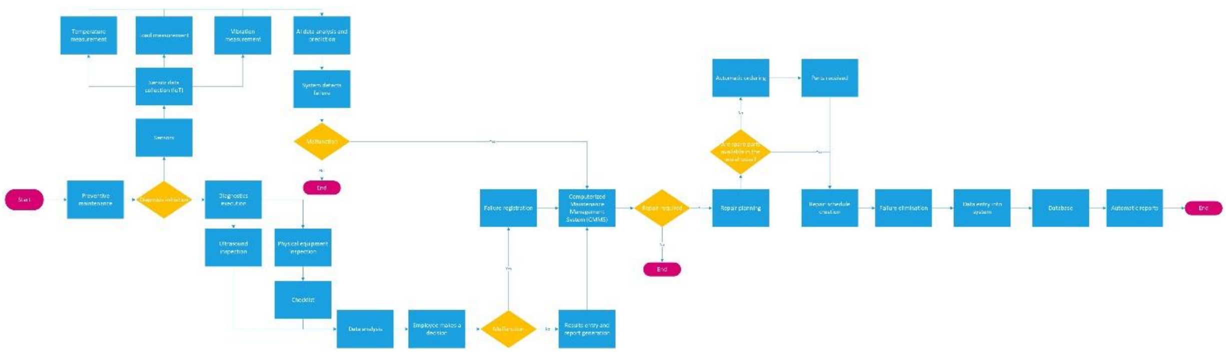

Figure 2. Improved maintenance process digitalization model (compiled by the authors)

To sum up, the improvement of the maintenance process illustrates the substantial benefits of transitioning from manual and fragmented operations to fully integrated digital systems. By leveraging real-time data, artificial intelligence, and IoT technologies, companies can enhance decision-making, minimize human errors, and streamline the entire maintenance workflow. This transformation not only increases operational efficiency and reduces equipment downtime but also strengthens the organization's ability to anticipate issues and respond proactively, leading to more resilient and data-driven maintenance practices.

6. Conclusions

The analysis of scientific sources revealed that the digitalization of maintenance processes in manufacturing companies is implemented through various model types, including diagnostic models, process efficiency improvement models, predictive models, and CMMS integration models. These models encompass both the analysis of the current situation and automated task allocation, forecasting, and resource planning. Digitalization tools such as Artificial Intelligence (AI), IoT sensors, CMMS systems, reporting tools, and data analytics solutions help automate processes, reduce the likelihood of errors and downtime, and improve the overall efficiency of the maintenance process. Each tool has its advantages and disadvantages, so their selection depends on company needs, IT readiness, and employee skills.

Based on the expert evaluation and in-depth interview responses, it was found that the implementation potential of the maintenance process digitalization model depends on several essential factors. In most companies, manual solutions such as Excel spreadsheets, logbooks, or verbal agreements are still used. Only a portion of the experts indicated that their companies already use CMMS or Power BI solutions. The experts identified the main challenges hindering digitalization: insufficient IT infrastructure, lack of employee skills, system incompatibility, and lack of management support. To ensure successful model implementation, it is recommended to apply digitalization solutions in stages, provide employee training, and strive for the integration of IT tools into a unified system to increase process efficiency.

Based on scientific literature, expert evaluations, and in-depth interview responses, the existing maintenance process was improved. In the standard process, most actions were performed manually, information was communicated verbally or recorded in separate systems, often using Excel spreadsheets or physical logbooks. As a result, these practices increased the risk of errors, slowed down information processing, and hindered effective process management. To address these challenges, the improved process integrates digitalization solutions such as Artificial Intelligence, Internet of Things (IoT) sensors (temperature, vibration, and load), and a Computerized Maintenance Management System (CMMS). All these components work in coordination: sensors collect data on equipment condition, AI analyzes the collected information and forecasts potential failures, and the CMMS system initiates tasks, checks spare part availability, and schedules maintenance. These integrated solutions ensure automated data flow, accurate planning, reduced error risk, and improved efficiency of maintenance processes. The system also generates reports that facilitate easier result analysis and real-time decision-making. A phased implementation approach is recommended, starting with process segments most susceptible to errors, such as planning, data recording, and task assignment. A gradual transition from the standard to the improved process would enable smooth integration within the company and increase the overall effectiveness of maintenance operations.

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