



Development of Digitalized Autonomous Maintenance to Simplify the Application of Autonomous Maintenance in The Automotive Part Industry

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Abstract. The development of the Industrial Revolution 4.0 has brought about a shift from traditional to digital work in various industries, including automotive. This article discusses the impact of digital transformation on operations in the automotive industry, particularly in terms of maintenance. To keep machine reliability and competitiveness, companies need to implement maintenance strategies such as Total Productive Maintenance (TPM) and Autonomous Maintenance (AM). However, challenges in discipline and consistency in AM implementation still exist. This article focuses on developing and implementing a Digital Autonomous Maintenance (DAM) Model in an automotive part company. The goal of DAM is to improve the effectiveness of AM activities through digital-based technology, making it easier for production operators to perform maintenance tasks efficiently and safely, and evaluate the success of the DAM model through a case study, comparing the reliability and performance of machines with and without DAM. The results are expected to supply insights for companies considering the implementation of AM and DAM in their maintenance strategy. Research Conclusion DAM simplifies and eliminates the AM documentation preparation process from 8 processes to zero, making AM activities more efficient and effective.

Keywords: Digital transformation, AM, DAM, Operational efficiency, TPM.

1 INTRODUCTION

Digital transformation has become a major focus in the manufacturing industry, including the automotive part industry. Maintenance, as one of the important aspects of a company's operations, requires a more sophisticated approach to improve efficiency and reduce downtime. Autonomous Maintenance (AM) is one of the Pillars and of Total Productive Maintenance (TPM), a concept developed in Japan in the 1970s. TPM aims to improve equipment effectiveness and extend equipment life by involving operators in maintenance tasks. This approach is based on the principles of operator responsibility, machine ownership, and continuous improvement. New Concepts and Architectures in Autonomous Maintenance (AM), such as references [1] Discuss Cyber-Physical Systems (CPS) and [2] Provide insight into system architectures that support automation and autonomous maintenance processes in the manufacturing industry. Seeing how CPS is implemented for autonomous maintenance can provide a basis for developing new models in digital autonomous maintenance, [3] Digital Twin

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provides new ideas for virtual representations of physical systems that can be used in more predictive and adaptive autonomous maintenance models. Digital transformation has become a major focus in the manufacturing industry, including the automotive part industry. Maintenance Systems, as one of the important aspects of a company's operations, require a more sophisticated approach to improve efficiency and reduce downtime. The Digital Autonomous Maintenance (DAM) model offers innovative solutions through the application of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analysis. [4]. The Use of Big Data and AI in Maintenance, [5] and [6] Focus on the use of AI and Big Data in Smart Maintenance. Examining how AI and big data are used for autonomous maintenance (AM) decision-making can be a new element, especially if research develops new algorithms or approaches in digital autonomous maintenance,[7] It also describes a proactive decision-making framework based on machine condition data. Research can expand or change this approach to add innovative elements such as deeper integration with real-time data. The application of digital technologies in smart manufacturing requires a comprehensive approach that covers various aspects of the organization, including technology readiness, employee competency, and support from management. Digital transformation is not only about technology but also about managing changes in organizational culture and business structure. The application of technologies such as the Internet of Things (IoT), data analytics, and machine learning has enabled the development of smarter and more efficient maintenance solutions. One prominent approach is Digital Autonomous Maintenance (DAM), which integrates digital technologies to improve equipment reliability and performance [9].

1.1 Background

Maintenance in the automotive industry has evolved from a reactive approach to predictive and now autonomous maintenance (AM). Digitally autonomous maintenance (DAM) models have evolved significantly, driven by technological advancements and the need for more efficient and effective maintenance practices. The following is a detailed description and background discussion of the development of digitally autonomous maintenance models. Digitally autonomous maintenance (DAM) builds on the traditional AM framework by integrating digital technologies to enhance its implementation and effectiveness. Key benefits of DAM include Continuous Improvement. The application of IoT and AI enables real-time monitoring of machine conditions and prediction of failures before they occur[10]. Digitally autonomous maintenance (DAM) is an approach to maintenance that uses digital technologies to check, analyze, and predict equipment maintenance needs. IoT sensors can collect operational data in real-time[11], which is then analyzed using machine learning algorithms to identify patterns and predict Maintenance needs, shows that Cyber-Physical System (CPS) architecture for Industry 4.0- based manufacturing systems can improve operational efficiency through DAM-enabled predictive maintenance. Research by [12] This study emphasizes the importance of integrating digital technologies in maintenance management to improve maintenance efficiency and effectiveness. It examines the implementation of autonomous maintenance in an automotive part manufacturer, highlighting the importance of improving machine and equipment availability through the adoption of digital technologies.

2 LITERATURE REVIEW

Initial development began with the reference to the Introduction to TPM Book. This book introduced Total Productive Maintenance (TPM) [13], which includes autonomous maintenance as one of its pillars. TPM emphasizes operator involvement in routine maintenance tasks to prevent equipment failure and improve overall equipment effectiveness (OEE). The originator of TPM, developed the concept of autonomous maintenance, which involves machine operators performing routine maintenance tasks, such as cleaning and lubrication, to prevent equipment failure and ensure its reliability.

Technology Integration, the implementation of autonomous maintenance in automotive part manufacturers highlights the benefits of integrating digital tools into autonomous maintenance practices. Digital tools such as computerized maintenance management systems (CMMS) and Industrial Internet of Things (IIoT) sensors enable realtime monitoring and data collection, improving maintenance efficiency and decision-making [14]. The development of a framework for implementing autonomous maintenance for the semiconductor industry emphasizes the importance of digital tools and platforms in improving maintenance efficiency[15].

The Role of Digital Technology, on the requirements of autonomous maintenance driven by digital twins. This study explores integrating digital twin technology into autonomous maintenance, highlighting the benefits of real-time data interaction and intelligent decision-making for predictive maintenance. This article discusses the impact of digital infrastructure on predictive maintenance, emphasizing the benefits of leveraging data and digital technologies to improve equipment reliability[16]. Digital technologies can enhance autonomous maintenance[17]. Research that discusses the integration of digital technologies into autonomous maintenance practices emphasizes the benefits of digital in maximizing production output and minimizing unplanned downtime. Autonomous Robotic System for Defect Inspection of Civil Infrastructure developed an autonomous robot system to inspect civil infrastructure for defects, utilizing digital twin technology to improve maintenance efficiency[18].

2.1 Digital Transformation in Manufacturing Industry

Digital transformation refers to the integration of digital technologies into all areas of a business, changing the way businesses operate and add value. [19]. In the manufacturing sector, this transformation includes process automation, increased operational transparency, and data-driven decision-making. Digital transformation has become a major focus across industries, including automotive part manufacturing. Technologies such as IoT, big data, and machine learning have been used to improve the efficiency and effectiveness of equipment maintenance, digital transformation in maintenance can reduce operational costs and improve equipment transmission through real-time condition monitoring and failure prediction. Digital Autonomous Maintenance (DAM) is a maintenance approach that uses digital technologies to check, analyze, and predict equipment maintenance needs. DAM integrates IoT sensors to collect real-time data, analyzes the data to analyze equipment condition, and machine learning algorithms to make correct maintenance predictions, DAM can reduce equipment downtime and improve operational efficiency by supplying prompt

maintenance recommendations. Predictive maintenance uses data from sensors to predict equipment failures before they occur, allowing for prompt preventive action.

Autonomous maintenance as a further evolution, uses AI to not only predict but also take automated actions based on the data received. IoT and Cloud Computing Predictive Maintenance[20] and [21] Provide an overview of how remote and cloud-based maintenance can be integrated with new technologies such as augmented reality and IoT. The research conducted can explore how these technologies can be further automated in digital maintenance systems[22]. Addressing downtime in production and supply chains, digital autonomous maintenance can be integrated with more energy-efficient or environmentally friendly models, which may not have been widely explored. Intelligent Maintenance Management Model[23]. Supplies insight into the research agenda related to intelligent maintenance. Examining new elements of autonomous maintenance, for example in the context of the automotive industry, can provide unique contributions, Industry 4.0 Technologies, and Cross-Platform Integration [24] and [25] Provide a framework on how Industry 4.0 and cross-platform integration can improve manufacturing efficiency, the research conducted finds gaps in how autonomous maintenance interacts with other platforms such as logistics, distribution, or supply chains in Industry 4.0 can add value to the research conducted.

2.2 Implementation of the DAM Model in the Automotive Industry

The use of the DAM model in the automotive industry can improve operational efficiency and reduce maintenance costs. Focus on the Automotive Sector. Some references such as autonomous vehicle networks can be the basis for developing more specific autonomous maintenance applications in the automotive part industry. Digital autonomous maintenance focusing on automotive part manufacturing companies has still not been fully explored. A study by [26] Shows that DAM implementation can reduce machine downtime and increase equipment life. Machine maintenance has a role in repairing, preventing, and analyzing data on the machine so that the machine can work in the best condition, encouraging autonomous maintenance program which is a concept of continuous maintenance program conducted between machine user and maintenance team including tightening, lubricating, and cleaning to maintain machine performance.

2.3 Research Problems

The development of the Digital AM Model originated from the obstacles and difficulties encountered when Production Operators carry out conventional AM activities. It requires cooperation, collaboration, and strong communication between Operators and Technicians in its implementation.

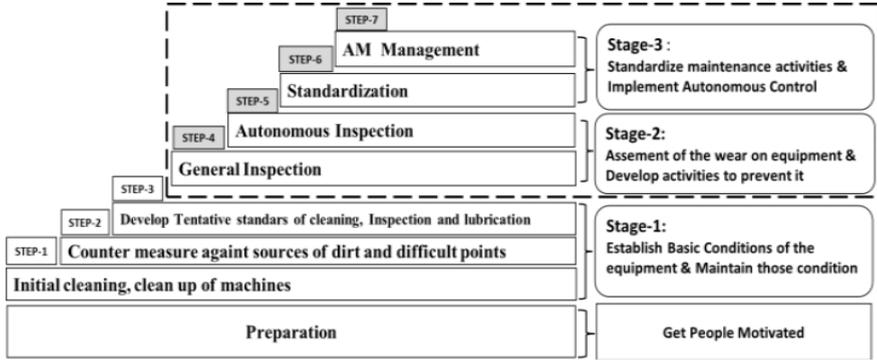


Fig. 1. Three stages and seven steps of AM

The results of research that have been conducted by several researchers provide information that there are still failures in the application of AM, and there are still industries that have not successfully implemented AM for various reasons [27], The general explanation from Figure 1 shows the potential obstacles and difficulties in implementing AM, so that the research conducted pays more attention to step-4, step-5, step-6, and step-7. Other problems in the implementation of AM activities are the implementation of machine checking still using paper sheets: 1. Difficulty in preparing documents, 2. Difficulty in document recapitulation, 3. Difficulty in document audit. The following Figure 2 Three obstacles in preparing the AM machine checklist document.



Fig. 2. Three obstacles in preparing AM machine checklist documents

The AM development plan makes a digital AM checking model (DAM) every machine checking instruction is stored in digital form on a tablet (smart device), connected to a machine that has been given additional sensors, IoT devices, and database servers so that parameter data can be collected to be processed into information as a decision in determining the condition of the machine when it will be used to operate, AM checking by operators can use Human Machine Interface devices in the form of touch screens on machines and the use of mobile phones, tablets or other smart devices. The development plan can be seen in Figure 2 below.

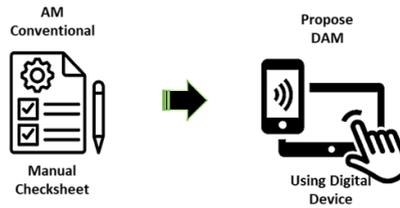


Fig. 3. Plan to develop AM into Digital AM (DAM)

From the explanation of the background and problems faced by the company, it can be formulated that the current implementation of AM still faces obstacles, especially the implementation of independent maintenance with the concept of checking machines that are still carried out manually with the checking method still using paper sheets in the form of machine checklists, so it is necessary to develop AM digitally to eliminate these obstacles.

3 METHODOLOGY

In this study, a DAM program that uses the JavaScript programming language with the React.js framework for the interface and the Node.js framework that functions as a server and a connector with the Postgre SQL database is proposed. In this study, the Use of the Digital AM Model (DAM) helps operators in checking machines, every information from the machine from the results of checking the machine checklist by the operator will be used as information on the condition of the machine used so that it can provide symptoms of abnormalities and machine status earlier before damage occurs, if an abnormality occurs the operator can immediately find out and make repairs themselves, if it has not been resolved the operator immediately contacts the technician to make repairs to the machine, the head of the section or manager can immediately find out the problems faced by the operator and find out the abnormal condition of the machine, the manager can find out and analyze the prediction of repairs and the need for spare parts that must be replaced to be prepared and scheduled for continuous repairs so that the production process is not disrupted due to machine damage. The development of this DAM model makes it easy for operators to enter and change the results of machine checks according to the current conditions (real-time), save, and send images to the database so that if needed when an audit and analysis are conducted, they can be at once available. A detailed explanation can be seen in Figure 3 as follows.

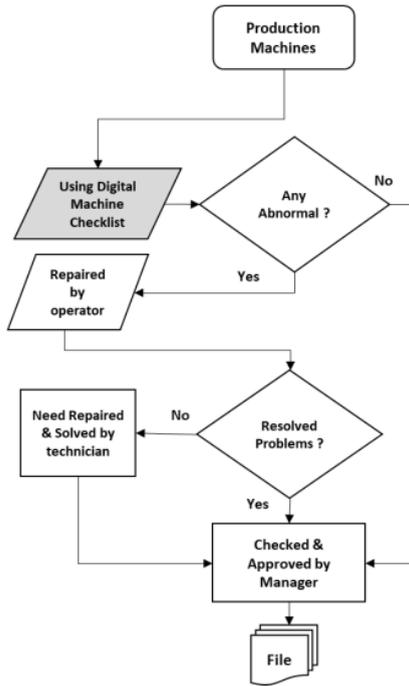


Fig 4. Flowchart of the proposed approach

DAM development will be applied to production process machines as a priority for 753 units of a total of 1110 machines. A detailed explanation can be seen in Table 1.

Table 1. List of Company Machinery

No	Department	Quantity (unit)
1	Production	753
2	Part Supply	248
3	Process Engineering	40
4	Utility	34
5	Machine Engineering	14
6	Quality	20
7	Others	3
Total		1110

Source data from companies that have been processed

4 RESULT AND DISCUSSION

The DAM development research was created to improve the understanding of independent machine maintenance by the production department or machine user operators to perform better machine maintenance and eliminate machine breakdown during use.

4.1 DAM Dashboard Display Result

The initial login display on the DAM System was created to make it easier to check the machine, DAM operators or users can log in according to their section level, Figure 5 Login Page as follows.



Fig 5. Login page of the Dashboard in DAM

Figure 5 provides a detailed explanation of the login method design by entering the `staff@gmail.com` email code with the `staff123` password or the `manager@gmail.com` email code with the `manager123` password to enter the DAM system. To display the Dashboard, the first page of the DAM system will look like Figure 4. Staff and manager-level users can use it to start checking machines by name, quantity, and area. This page explains and provides information about the Checklist status: Approved checklists, checklist statuses that need to be approved and unapproved checklists, and Early warning systems with explanations using abnormal component status graphs (not okay).

4.2 Machine Condition Display Results

The Machine condition status information display can provide information on engine conditions and locations, and engine details according to the name, type, and engine number, by clicking "view" you can see the component details sent by the operator when checking the engine. Figure 6 Machine Condition Status Display.

4.4 File Menu Display Results

The File Menu display on DAM provides information on machine check result data that can be saved and printed as needed, on the checklist data file download display, users can select the machine name, month period, and request to the database by pressing the "Sent" button, after waiting 2~5 seconds the desired data can be checked in the download folder on the device used to view the machine checklist results during the selected period, To exit the DAM system, the operator or machine user performs a checklist by pressing the "Logout" button, so that the DAM System returns to its initial position again. A detailed explanation can be seen in Figure 7 EMC DAM File Download Display as follows.

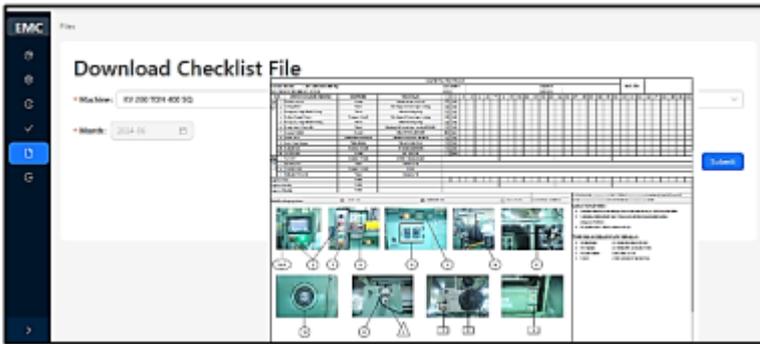


Fig. 8. DAM File EMC Download View and Logout

4.5 Discussion

The implementation of digital Autonomous Maintenance (DAM) makes machine checking and independent maintenance (AM) activities carried out by operators manually using machine checklist sheets (paper base) into AM activities using digital forms (paperless). Users can directly fill in the checklist in Excel format on a tablet that is integrated with storage on the central computer. So that the recapitulation and document search process can be done easily by the computer without human intervention. This application can eliminate the stages of AM activities by checking the previous checklist machine, eliminating 4 waste works, namely storage, transportation, waiting time, and the process itself. Machine check data is stored on the data center server and can be accessed in real-time. This website-based program is a checklist machine that is converted into digital form with a more attractive and easy-to-fill display. Users only need to fill in the machine number and the checklist points will appear as usual. Filling in points can also be done easily on any device. The checklist data that has been filled in on the DAM will automatically be filled in on the checklist sheet and can be accessed with just one click download. The results of DAM development can reduce piles and paper usage and avoid the potential for human error. Machine checks with easy and attractive access can facilitate the filling and approval process from leaders or managers, and facilitate data search and recapitulation so that it can reduce machine checking time and can be monitored in real-time. Managers can also more easily control checklist data for approval, users log in to the approval page

then users only need to fill in the machine number and the week of the checklist period to be approved. Detailed explanations can be seen in Figure 9 as follows.



Fig. 9. DAM File EMC Download View and Logout

4.6 Simplification of AM Machine-Checking Activities

The concept of a manual AM Checking Model is proposed using a digital AM Checking Model. The implementation of activities in Step 4,5,6,7 is included in the form of a digital machine checking system as a development of the AM system model from a conventional system to a digital AM system by adding an AM work instruction program into digital form. The development of the DAM model allows companies to eliminate the preparation process and the implementation of independent maintenance (AM) can be more focused, shorten the preparation time, and maintain consistency and commitment to the implementation of AM so that machine damage and machine safety can be maintained properly. A detailed explanation can be seen in Figure 10.

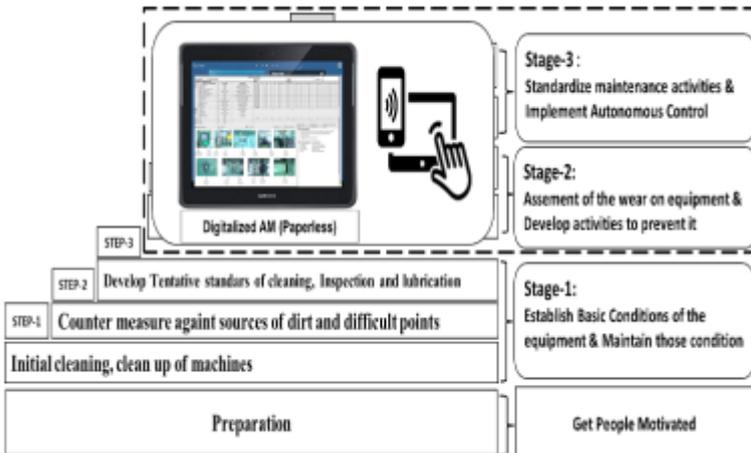


Fig. 10. Implementation DAM Concept

A summary of the development of the Digital Autonomous Maintenance (DAM) application The comparison table explains again the advantages of the Digital

Autonomous Maintenance development research, such as time efficiency, simplifying the activities of preparing documentation that has been made easier in operating and checking the machine, reducing the use of paper sheets so that it can save paper and reduce costs. This can be seen in Table 2 as follows.

Table 2. Comparison After Implementation DAM

Criteria	AM Conventional	Digital AM
Obstacle	Preparing Documentation 4 days	0
	Recapitulation: 2 days.	0
	Document Storage needs storage	0
AM Concept	Manual	Digital
Cost	Print-out checksheet ;	
Document	@500 IDR x 735 =	0
AM Check sheet	376,500 IDR	
	Ink Printer: 75% x	
	4,000,000 IDR =	0
	3,000,000	
Preparation	8 Process using	0 Process
Machine Checklist	hardcopy (paper base)	
Pollution	not yet done	0

Source data from companies that have been processed

5 CONCLUSION

Conventional AM activities by checking machines through the use of paper machine checklists that were initially inefficient are now concise and easy due to the development of digital AM models. This has a major impact on the efficiency of working time with the existence of paperless forms, which can cut costs and reduce carbon dioxide output due to the use of paper issued for checklist activities every month. It is hoped that this machine checklist activity can continue to develop until the formation of data digitalization in the future, this needs to be prepared to adapt to technological developments.

The newly proposed Digital Autonomous Maintenance (DAM) system is carried out for the efficiency of monitoring and checking machine functions in the Industry so that the process of maintenance, care, and repair of machines when there are symptoms of abnormalities or potential damage can be handled properly and quickly. The DAM system allows companies to monitor machine conditions immediately in real-time to maintain and improve productivity. Digital Automated Maintenance (DAM) is a powerful tool for optimizing maintenance processes, and care and increasing equipment efficiency. By combining digital technology and empowering employees and managers, DAM can improve reliability, reduce downtime and machine breakdown repair costs, and improve employee safety and engagement. Successful DAM

implementation requires a strong foundation in training and validation, the use of digital tools, and a continuous improvement process.

5.1 Limitation

This study has several limitations, including The scope of the data is limited to one company in the automotive industry, so generalization of the results to other sectors may be limited. Challenges in obtaining complete and accurate historical data, especially for indirect costs such as hidden downtime. DAM development can be continued by integrating with established and stable systems as part of smart manufacturing according to company needs, for example by integrating the DAM system into the ERP system.

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