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Systematic Literature Review: Application of Work System from Lean Maintenance and its Methodology

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ABSTRACT

Maintenance is an activity in maintaining and repairing a machine, with the most dominant factor being the increase in downtime. This can lead to a decrease in production output and an increase in production costs. Therefore, it is necessary to understand the maintenance repair system on the machine. Reliability-based maintenance is used to plan maintenance intervals for machines, equipment, or components that frequently experience failures. Thus, the maintenance system becomes efficient. This study aims to determine the implementation of Lean Maintenance (LM) in machine maintenance. The method used to review previous studies employs a systematic literature review. The data process was carried out by identifying, evaluating, and interpreting those related to the topic of machine maintenance. Based on the research conducted, machine maintenance using the lean maintenance (LM) approach has been proven in all reviewed scientific articles to show an efficiency increase of 60.7%, a reduction in downtime, and the ability to determine maintenance schedules. The review includes the categorization and application of the lean maintenance approach based on three parameters: technique, principle, and scope. The maintenance tools or techniques most commonly used in waste reduction are Maintenance Value Stream Mapping and Reliability-Centered Maintenance.
Keyword: Lean Maintenance, Maintenance Efficiency, Downtime, Systematic Literature Review

ABSTRAK

Pemeliharaan merupakan aktivitas dalam menjaga dan memperbaiki suatu mesin, dengan faktor peningkatan waktu henti yang paling dominan. Hal ini dapat menyebabkan hasil produksi berkurang dan biaya produksi bertambah. Oleh karena itu, perlu dipahami sistem perbaikan pemeliharaan pada mesin. Pemeliharaan berbasis keandalan digunakan untuk merencanakan interval pemeliharaan pada mesin, peralatan, atau komponen yang sering mengalami kerusakan. Sehingga, sistem pemeliharaan menjadi efisien. Penelitian ini bertujuan untuk mengetahui implementasi penerapan Lean Maintenance (LM) pada pemeliharaan mesin. Metode yang digunakan untuk mengkaji penelitian-penelitian terdahulu menggunakan tinjauan literatur sistematis. Proses data dilakukan dengan mengidentifikasi, mengevaluasi dan meninterpretasikan yang terkait pada topik pemeliharaan mesin. Berdasarkan penelitian yang dilakukan, pemeliharaan mesin menggunakan pendekatan lean maintenance (LM) terbukti di semua artikel ilmiah yang telah ditelaah menunjukkan peningkatan efesiensi sebesar 60.7%, pengurangan waktu henti dan dapat menentukan jadwal pemeliharaan. Tinjauan tersebut mencakup kategorisasi dan aplikasi pendekatan lean maintenance yang didasarkan pada tiga parameter yaitu teknik, prinsip dan ruang lingkup. Alat atau teknik pemeliharaan yang paling banyak digunakan dalam pengurangan pemborosan adalah Maintenance Value Stream Mapping dan Reliability-Centered Maintenance.
Keyword: Lean Maintenance, Efesiensi Pemeliharaan, Waktu Henti, Tinjauan Literatur Sistematis

1. Introduction

Maintenance is the activity of keeping and repairing a machine that has experienced damage or before damage occurs. The more frequently the machine is operated, the greater the maintenance required [1]. Damage to the machine can result in a halt in the production process, so maintenance is necessary to ensure that the machine continues to function according to standards and achieves optimal efficiency [2]. The research by Lim et al. [3] shows that failure to perform routine maintenance is the main cause of machine damage. The efficiency of a machine refers to how well the machine converts input energy or resources into the desired output [4]. The improvement of operational efficiency in maintenance is expected to reduce downtime, maintenance costs, and minimize non-value-added activities in repairing or performing maintenance activities [5].

Maintenance efficiency is important in reviewing how effectively time, labor, and costs are utilized in maintenance activities to achieve the goals [6]: (1) extending machine life, (2) increasing equipment availability, and (3) reducing downtime. Downtime is the interval of time when equipment or systems do not operate normally. The increase in downtime is caused by non-value added (NVA) activities or waste [7]. According to Azhari et al. [8], one of the strategies to eliminate waste in maintenance operations is the application of lean principles to all maintenance activities. The application of lean principles in maintenance allows organizations to optimize processes by reducing waste, improving operational efficiency, and enhancing equipment reliability. This directly contributes to the overall increase in productivity and profitability [9].

According to Greenough et al. [10], investigations into the application of lean principles in maintenance in previous research are very limited. The researchers emphasize the need for more studies on the application of lean manufacturing principles in maintenance operations. According to Ghayebloo et al. [11], a model was formulated to determine the minimum maintenance requirements and satisfactory reliability levels through the use of lean concepts. The research by Fourie et al. [12] employed a combined approach of Quality Function Deployment (QFD) and Analytic Hierarchy Process (AHP) to evaluate the importance of a set of maintenance excellence criteria and prioritize lean tools against these criteria. According to Shagluf et al. [13], Lean Maintenance is the foundation of physical maintenance and a technique used to develop preventive maintenance and scheduled maintenance. This is based on lean principles to optimize process efficiency and the performance structure to be achieved, in the form of an effective maintenance design function to ensure the reliability of machines and equipment [14]. Lean Maintenance can reduce downtime and minimize non-value-added activities that may occur when machines experience unexpected failures [15].

According to Mostafa et al. [16], they introduced a framework for measuring maintenance strategies based on lean maintenance and agile components, which involve the elimination of waste and downtime in maintenance activities. However, the integrative lean structure in maintenance activities has not yet been fully established. The principles of lean and agile include reducing activities that do not add value, standardizing maintenance procedures, and optimizing maintenance methods. According to Womack et al. [17], lean can be implemented in various manufacturing and service sectors to improve efficiency and reduce waste.

Therefore, this research focuses on the importance of a comprehensive and systematic lean maintenance approach to the published literature. The main objective is to deepen the understanding of the importance of implementing the lean maintenance system as an approach to improving maintenance methods. Discussion on the basic principles of lean maintenance, its benefits, challenges, and relevant case studies is expected to provide an in-depth understanding of the lean approach and offer recommendations for better implementation in the industry.

2. Method

This research uses the systematic literature review method with several stages; planning, implementation, and reporting. The purpose of SLR is to summarize previous research that has empirical evidence and suggestions for future research [18]. The planning stage involves identifying the needs from the literature review, by searching for research sources relevant to the keywords "lean maintenance," "machine maintenance methods," and "downtime." The implementation stage begins with searching for previous research using several databases. The criteria for searching articles discussing the lean maintenance approach were obtained from Google Scholar, ScienceDirect, and Scopus journal sites, resulting in the identification of 10 journals that

meet the review requirements. The search results of the articles are collected and extracted so that they can be synthesized and produce a research report. The reporting stage will explain the results of the research that has been conducted [18]. The selection of article criteria in the Systematic Literature Review (SLR) method for the topic of lean maintenance is carried out by presenting real results from the implementation of lean maintenance, such as increased efficiency, reduced downtime, or cost savings, because they provide empirical evidence that enriches the analysis.

3. Results and Analysis

3.1. Implementation of Lean Maintenance

The first step in lean maintenance is to identify the types of waste in the maintenance process [10]. The core concept of lean is to eliminate the seven main forms of waste. The seven main types of waste in the maintenance process can be discussed in the same way as the eight types of waste identified in production systems [10], [19].

The principles and application of lean maintenance not only rely on eliminating waste throughout the maintenance process but also on reducing downtime and scheduled maintenance. The machine maintenance system with a lean maintenance approach is increasingly becoming a primary focus in academic literature and industrial practice. A summary of the author's research on how the implementation of Lean Maintenance (LM) contributes to reducing downtime, non-value-added activities, and improving efficiency in maintenance operations is presented in Table 1.

Table 1. Implementation of Lean Maintenance in the Machine Maintenance Repair Work System

No	Research Findings	Journal
1	Developing maintenance strategies	[13], [16], [20]
2	Improving preventive maintenance planning	[16], [21]
3	Increasing productivity	[13], [22]
4	Enhancing maintenance efficiency	[22], [23]
5	Improving machine performance	[24], [25]
6	Reducing machine downtime	[21], [23], [25], [26]
7	Lowering maintenance costs	[21], [24]
8	Minimizing non-value-added activities	[22]

Maintenance strategies should include damage prevention through routine maintenance, real-time monitoring of equipment conditions to detect issues before failures occur, as well as timely repairs to minimize production disruptions; this is referred to as developing effective maintenance strategies [20]. Shagluf et al. [13] conducted research on important steps in lean that can improve operational efficiency and reduce machine downtime.

Derlini et al. [26] conducted research on the optimization of maintenance procedures to enhance the reliability and operational efficiency of machines. The benefits of this research include more structured maintenance and an improvement in the technical competencies of maintenance personnel, which overall contributes to increased machine availability and stability in the production process. Zenna [25] conducted research on Improvement of CNC machine quality with predictive maintenance type. This research evaluates the effectiveness of using sensors and Internet of Things technology. (IoT).

In addition, a planned maintenance schedule is important to ensure that the machines operate optimally. The research by Mostafa et al. [16], Karningsih et al. [21], and Amirachman et al. [25] conducted an analysis on the increase in downtime. The cause of the increase is the lack of a regular maintenance schedule, which has resulted in damage to the CNC machine. The advantage of this research is that there is technology available that allows for real-time monitoring and analysis of machine conditions, enabling the early identification of potential issues and optimizing maintenance schedules to minimize disruptions in the production process.

Several studies focus on lean principles to minimize waste in maintenance operations. Research conducted by Muzaki in 2017 on machine maintenance analysis. Researchers categorize maintenance strategies within the framework of lean maintenance principles, which are (a) identifying and reducing time waste; (b) waste of maintenance and repair costs; and (c) waste of resources, analyzing maintenance processes to ensure that

resources are used optimally, with attention to better spare parts inventory management and technician training to enhance operational efficiency. The limitation of this research is that it cannot analyze time and costs.

Meanwhile, Nico's research in 2023 on the Analysis of Machine Maintenance Schedules [24] successfully applied lean principles in maintenance operations, namely: (a) Reducing unproductive downtime by optimizing maintenance schedules and improving planning processes; (b) evaluating expenditures on spare parts and labor, as well as implementing cost-efficiency techniques such as condition-based maintenance to reduce the need for emergency repairs and associated costs; and (c) providing ongoing training for technicians and maintenance personnel to ensure that technicians possess the necessary skills to effectively apply lean principles.

3.2. Maintenance Methods

Based on the findings of several previous studies, the researchers used methods in the implementation of lean maintenance. Table 2 shows the methods used in the findings of several researchers.

Table 2. Metode Lean Maintenance

Maintenance Method	Journal
Maintenance Value Stream Mapping (MVSM)	[10], [11], [13], [14], [15], [16], [20], [25], [23], [22]
Reliability-Centered Maintenance (RCM)	[8], [11], [14], [21], [22], [24], [27]
Total Productive Maintenance (TPM)	[20], [26]
Overall Equipment Effectiveness (OEE)	[9],[10]
Failure Mode and Effects Analysis (FMEA)	[4], [11]
Root Cause Analysis (RCA)	[8],[14]
Single Minute Exchange of Die (SMED)	[7], [28]
Poka Yoke	[28]
5S	[28], [15]
Agile	[16]

Reducing non-value-added activities in maintenance can be achieved through identifying causes with Maintenance Value Stream Mapping (MVSM) [22]. The lean maintenance practices suitable for maintenance activities have been stated in previous studies. Mostafa et al. [16] identified key lean tools including Maintenance Value Stream Mapping (MVSM) and agile.

According to the research by Muzaki et al. [22], Reliability-Centered Maintenance (RCM) helps minimize excessive maintenance, thereby reducing maintenance costs. Igba et al. [27] state that the analysis of Reliability-Centered Maintenance (RCM) aids in enhancing machine reliability by identifying potential failures earlier and implementing appropriate maintenance strategies to prevent machine breakdowns.

Clarke et al. [28] suggest lean tools that are suitable for an organization's maintenance process. These tools include Single Minute Exchange of Die (SMED) and Poka Yoke. (pengendalian kesalahan). Correia et al. [15] state that applying 5S in a clean, organized, and efficient work environment can reduce downtime by 30-50% and extend the lifespan of equipment. Yile et al. [29] aim for the success of manufacturing through eight lean maintenance practices as a preparation to achieve lean project goals in manufacturing.

Meanwhile, the research by Ghayeblo et al. [11] addresses machine failures due to the absence of a routine maintenance schedule by applying the Failure Mode and Effects Analysis (FMEA) method to analyze and calculate the Risk Priority Number (RPN) of the failures that occur. Jiang et al. [4] analyze the fundamentals of Failure Mode and Effects Analysis, providing strong results for decision-making, allowing maintenance strategies to be more effective and efficient.

The weakness of the lean maintenance approach focuses on reducing waste (non-value-added activities) and improving process efficiency. However, in environments with high variability, such as industries with fluctuating demand or frequently changing technology, the lean approach often lacks flexibility [3].

The types of machines used in the manufacturing industry vary. Some use CNC machine systems, while others use manual machines. This has not yet received the attention of researchers in maintenance methods. Meanwhile, maintenance methods influence the reduction of downtime and the improvement of efficiency. So that it can become material for further research.

Based on the summary of previous research articles, a total of 30 items published between 2012 and 2024 were obtained. Figure 1 shows the publications featured in various conference proceedings, national and international journals, related to the application of lean maintenance.

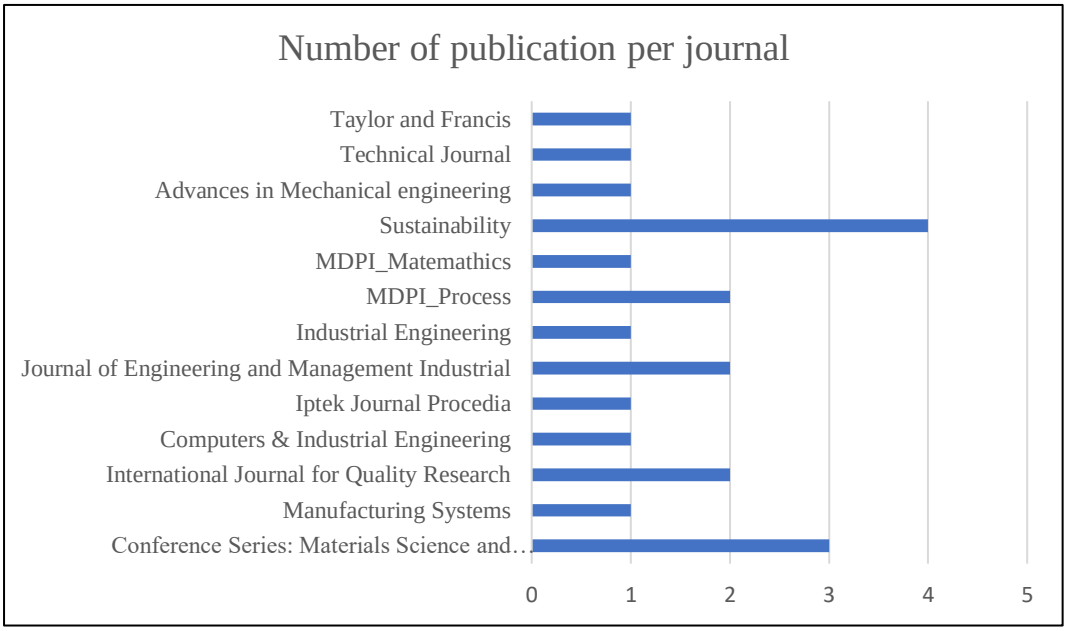

Figure 1. Proportion of Publication Sources Published Sources

4. Conclusion and Recommendations

This research presents a systematic literature review focusing on the lean maintenance approach in maintenance operations. The review covers the categorization and application of lean maintenance approaches and provides an analysis of their advantages and limitations. Based on this research, the researchers can suggest a lean maintenance categorization system based on three parameters; techniques, principles, and scope. The findings reveal that maintenance measures can be related to the entire production line or specific equipment. The lean maintenance approach is largely for case studies using the Maintenance Value Stream Mapping method at around 60.7%. Related to the lean principle, the main focus of lean maintenance is on improving efficiency (time and cost) in maintenance operations. The implementation of lean maintenance is very relevant, as this approach combines team involvement and accountability in maintenance efforts.

Future research should focus on the use of technologies such as the Internet of Things (IoT) and predictive analytics to enhance the Lean Maintenance approach in machine efficiency analysis, employee training, and continuous improvement in the manufacturing industry.

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