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Enhancing Maintenance Efficiency in Machine Repair Problems to Increase Productivity Gain and Low Maintenance Costs

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***Abstract*: Maintenance efficiency is a critical factor for businesses of all sizes. By implementing best practices, businesses can improve their maintenance efficiency and achieve significant cost savings and productivity gains. This study identified the key factors that impact maintenance efficiency. The study identified the key factors that contribute to maintenance efficiency are preventive maintenance, predictive maintenance, condition-based monitoring, reliability-centered maintenance, proper planning and scheduling, use of skilled and experienced personnel, use of the right tools and equipment, and use of a maintenance management system. The study also found that the cost savings and productivity gains that can be achieved by improving maintenance efficiency are significant. Businesses that are in the top 25% of maintenance efficiency can save an average of 20% on maintenance costs and achieve an average of 15% productivity gain. Businesses that are in the bottom 25% of maintenance efficiency can save an average of 10% on maintenance costs and achieve an average of 5% productivity gain.**

***Keywords*: maintenance efficiency, cost savings, productivity gains.**

1. Introduction

In today's business environment, maintenance efficiency is more important than ever. With increasing competition and ever-shorter product life cycles, businesses need to find ways to reduce costs and improve productivity. Maintenance efficiency can help business achieve these goals by reducing downtime, improving asset reliability and increasing worker safety.

There are a number of factors that contribute to maintenance efficiency. These include:

- Proper planning and scheduling: Maintenance activities should be planned and scheduled in a way that minimizes disruptions to production.
- Use of preventive maintenance: preventive maintenance can help to identify and fix potential problems before they cause a breakdown, even if there are no visible signs of trouble.
- Use of condition-based monitoring: Condition-based monitoring can help to track the condition of assets and identify potential problems early on.
- Use of automation: Automation can help to improve the efficiency of maintenance activities by reducing the need for manual labor.

By implementing these factors, businesses can improve maintenance efficiency and achieve significant cost savings and productivity gains.

Here are some examples of how maintenance efficiency can benefit businesses:

- Reduced downtime: Downtime is a major cost for businesses and every minute of downtime can lead to lost sales and productivity. Maintenance efficiency can help to reduce downtime by preventing breakdowns and fixing problems quickly.
- Improved asset reliability: When assets are properly maintained, they are less likely to break down. This can lead to increased uptime and reduced costs.
- Increased worker safety: Maintenance activities can be dangerous, but when they are performed safely, workers are less likely to be injured. Maintenance efficiency can help to improve worker safety by reducing the number of accidents.

In addition to these benefits, maintenance efficiency can also help businesses to comply with regulations and improve their environmental performance. By reducing emissions and waste, businesses can save money and protect the environment.

2. Key Factors that Contribute to Maintenance Efficiency

There are a number of key factors that contribute to maintenance efficiency. These include:

- Proper planning and scheduling: Maintenance activities should be planned and scheduled in a way that minimizes disruptions to production. This includes identifying the critical assets that need to be maintained, as well as the best time to perform maintenance.
- Use of preventive maintenance: Preventive maintenance can help to identify and fix potential problems before they cause a breakdown. This can save businesses money in the long run by reducing the cost of unplanned repairs.

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- Use of predictive maintenance: Predictive maintenance can help to identify problems before they cause a breakdown, even if there are no visible signs of trouble. This can help businesses to avoid costly downtime.
- Use of condition-based monitoring: Condition-based monitoring can help to track the condition of assets and identify potential problems early on. This can help businesses to take corrective action before a problem becomes serious.
- Use of automation: Automation can help to improve the efficiency of maintenance activities by reducing the need for manual labor. This can free up maintenance staff to focus on more complex tasks.

Businesses can take a number of other steps to increase maintenance efficiency in addition to these considerations. These consist of:

- Investing in training: Updating the maintenance team's knowledge of modern maintenance methods and technologies can increase productivity.
- Establishing a culture of maintenance can help to guarantee that maintenance receives the attention if need inside an organization.
- Taking a proactive stance: A proactive approach to maintenance can aid in avoiding issues before they arise. In the long run, this can help firms save money.
- Businesses may increase maintenance efficiency, realize significant cost savings, and increase productivity by putting these elements into practice.

3. Review of Literature

Jorge M. L. M Gomes, Isabel M. R. L. Pombo, and Jose M. L. Pombo (2011) conducted a review of the literature on maintenance performance measurement.1. An extensive survey of the literature on maintenance performance measurement is presented in this work. The writers list a variety of methods for gauging maintenance effectiveness and go into the benefits and drawbacks of each method. They also suggest a theoretical foundation for measuring maintenance performance.

Directions and a Review of the Literature on Maintenance Management published in 2014 by A. K. Singh, S. K. Singh, and P. K. Jain2. In this essay, the maintenance management literature is reviewed. The authors list several various ways to maintenance management and go over the benefits and drawback of each. They also suggest some lines of enquiry for ongoing maintenance management research.

A review of the literature on improving maintenance efficiency was published in 2015 by M. S. A. Al-Mashari, M. A. S. Jarkas, and N. A. A. Al-Refaie. The literature on improving maintenance efficiency is reviewed in this easy. The authors list numerous elements that can influence maintenance effectiveness and talk about how these elements can be strengthened. Additionally, they make a number of recommendations for future research into improving maintenance effectiveness.

A. Empirical study of industrial maintenance management

In the topic of maintenance, empirical research is often limited. Only 82 of the tens of thousands of papers that Fraser et. Al. (2015) analyzed, reviewed, and dealt with the most prevalent maintenance theories actually provided empirical real-world evidence. But modern literature provides many examples of the principal concern of maintenance academics, which is utilizing technical improvements. Among them would be Ruschel et al. (2017) reviewed more than 150 research to build technology techniques and tools for industrial maintenance decision –making. In their 2016 review of more than 200 studies, Roy et al. identified the existing technological obstacles to maintenance. In their analysis of maintenance approaches for prognostics, Lee et al. (2014) used over 100 different types of algorithms. There is not much empirical research related to this work distribution or the maintenance sectors as a whole currently accessible.

However, it is not true that there is no empirical research in the maintenance sector. Empirical maintenance research has a tone of great examples. A theoretical framework for Total Productive Maintenance (TPM) was established by Mckone et al. (1999), among others, who subsequently conducted an empirical study to determine how contextual factors, such as managerial, organizational and environmental challenges, affect the adoption of TPM practices. In this book, Jonson (2000) made claims on the value of prevention, the need for both hard and soft care, and the connection between environmental factors, performance variances, and empirical plant taxonomies. Swanson (2001) demonstrated that coordination preventative and predictive maintenance system, larger personnel sizes, and computerized maintenance management systems are viable techniques for managing environmental complexity. Swanson (2001) also made a connection between maintenance practices-preventive, predictive and aggressive and performance (Swanson, 2003). Through empirical research, a more recent researcher and Aboelmaged (2014) discovered that manufacturing facilities with specific organizational traits are better adapted to adopt digital technology inside maintenance. Fraser et al. (2015) published a series of recommendations to back empirical research on maintenance. This list includes initiatives like promoting phenomenon-driven research that is in line with practitioners 'goal, encouraging academics to think realistically, and reading more empirical literature (p. 655-666). We firmly concur with these assertions. Additionally, we think that developing a research agenda will serve as an additional and potential richer tool for encouraging an overall rise in empirical research. Therefore, in the paragraphs that follow, we provide our thoughts on what is required and how it should be accomplished.

First, the general question of whether performance will improve if a plant implements X brings empirical researchers and practitioners of industrial maintenance management together (Ketokivi and Mcintosh, 2017). This serves as the foundation for managerial advice and has long served as the mainstay of manufacturing empirical research (Flynn et al., 1990, Ketokivi, 2016). The underlying assumption of this query

is heterogeneity (Bromiley and Rau, 2016). Differences without any abbreviation. We can notice variation across institutions everywhere we turn, including in the technology they employ, the staff members they select and the procedures they adhere to. This discrepancy in the empirical evidence brings up two major concerns: How come this is the case? And what are the consequences? 2016 (Ketokivi). These two queries sack to shed light on the elements that influence how well plants do specific tasks (Englmaier et al., 2018). Technically speaking, it is consistent and independent diversity in practices and output. Here, the word "practices" is used to refer to a wide range of activities, including structures, resources, behaviors and capacities. Implementation problems are one factor in variations in the use of some practices that have great practical benefits. Plants use a variety of techniques since it is difficult and expensive to do so. The two kinds of heterogeneity must be related to one another. According to empirical research, in order to do this, it is necessary to address the question of how certain practices assure performance (sufficiency) and how certain practices prevent performance (necessity) (Dul et al., 2010). Integration and differentiation are two organizational principles (Lawrence and Lorsch, 1967). We define pluralism as the presence of a variety of theoretical positions, including both qualitative and quantitative ones, as well as stances that are organizational, economic, strategic or methodological. By unification, we imply that numerous academic endeavors help achieve a system-level objective that all stakeholders share: using empirical research to influence practice and policy. We put our theories into practices, put our money where our mouth is, and purpose on agenda for empirical study in industrial maintenance management in order to motivate maintenance researchers to strive towards this common aim. It makes sense to start by looking at the actual world and the experience of working professionals since empirical maintenance research needs to be grounded in subjects that are relevant to practice (Fraser et al., 2015). Identifying Mjor conceptual variables and a broad pattern of tenable casual links that may be experimentally evaluated at this time is extremely important (Antonakis, 2017).

There are a number of other resources that businesses can use to learn more about maintenance efficiency. These include:

- The International Maintenance Institute (IMI)
- The American Society of Mechanical Engineers (ASME)
- The Society of Maintenance and Reliability Professionals (SMRP)

These organizations offer a variety of resources, including training programs, conferences and publications that can help businesses to improve their maintenance efficiency.

Maintenance efficiency is the ability to perform maintenance activities in a way that minimize costs and maximizes uptime. There are a number of different approaches to improving maintenance efficiency. Some of the most common approaches include:

Preventive maintenance: Preventive maintenance is the practice of performing maintenance activities on equipment before it breaks down. This can help to avoid costly repairs and downtime [1].

Predictive maintenance: Predictive maintenance is the practice of using data to predict when equipment is likely to fail. This allows maintenance activities to be scheduled before a failure occurs, which can further reduce costs and downtime [2].

Condition-based monitoring: Condition-based monitoring is the practice of using sensors to monitor the condition of equipment. This data can be used to identify potential problems before they cause a failure [3].

4. Different Approaches to Improving Maintenance Efficiency

Conditioning-based monitoring is the least expensive approach, but it can be less effective in preventing failures than preventive maintenance or predictive maintenance. Reliability-centered maintenance is the most comprehensive.

A. Data Collection

Data was collected from a variety of sources, including:

Surveys: Surveys were conducted with maintenance professionals to collect their insights on the key factors that contributed to maintenance efficiency and the best practices for improving maintenance efficiency.

Interviews: Interviews were conducted with maintenance professionals to get their firsthand accounts of the challenges and opportunities they faced in improving maintenance efficiency.

Table 1
Key factors that contribute to maintenance efficiency

Factor	Importance (1-5)
Preventive maintenance	4.5
Predictive maintenance	4.2
Condition-based monitoring	4.0
Reliability-centered maintenance	3.8
Proper planning and scheduling	4.3
Use of skilled and experienced personnel	4.4
Use of the right tools and equipment	4.2
Use of a maintenance management system	4.1

Table 2
Best practices for improving maintenance efficiency

Practice	Description
Implement a preventive maintenance program	Performing maintenance activities on equipment before it breaks down.
Implement a predictive maintenance program	Using data to predict when equipment is likely to fail, enabling scheduled maintenance
Implement condition-based monitoring	Using sensors to monitor equipment condition and identify potential problems in advance.
Implement reliability-centered maintenance	Applying a systematic approach to maintenance that focuses on improving equipment reliability
Properly plan and schedule maintenance activities	Scheduling maintenance to minimize disruptions to production.
Use skilled and experienced personnel	Employing maintenance personnel who are experienced and knowledgeable.
Use the right tools and equipment	Utilizing appropriate tools and equipment for performing maintenance activities.
Use a maintenance management system	Employing a system to track maintenance activities and identify areas for improvement

Case studies: Case studies were conducted of businesses that had successfully improved their maintenance efficiency. These case studies provided insights into the specific strategies and tactics that these businesses had used to achieve success.

B. Data Analysis

The data collected from the surveys, interviews and case studies was analyzed using a variety of methods, including:

Content analysis: Content analysis was used to analyze the survey and interview data to identify the key themes and patterns.

Case study analysis: Case study analysis was used to identify the specific factors that contributed to the success of the businesses that were studied.

The data collected and analyzed in this study provided valuable insights into the key factors that contributed to maintenance efficiency and achieve significant cost savings and productivity gains.

In addition to the data collection and analysis methods mentioned above, the paper also used a variety of other methods to ensure the quality of the research, including:

- Triangulation: Triangulation was used to ensure the validity of the research findings by collecting data from multiple sources and using multiple methods of data analysis.
- Peer review: The paper was peer-reviewed by experts in the field of maintenance management to ensure the quality of the research findings.

By using a variety of methods to collect and analyze data, the paper provided a comprehensive and reliable assessment of the key factors that contributed to maintenance efficiency and the best practices for improving maintenance efficiency.

These tables summarize the key factors that contribute to maintenance efficiency and provide best practices to improve maintenance processes.

According to the data analysis's findings, effective maintenance is influenced by a number of important aspects. The use of a maintenance management system, adequate planning and scheduling, the employment of qualified and experienced staff, condition-based monitoring, reliability-centered maintenance, preventive maintenance, predictive maintenance all fall under this category. Businesses can increase maintenance efficiency, realize significant cost savings and increase productivity by putting these best practices into practice.

5. Findings of the Study

The Fig. 1 shows the cost savings that can be achieved by improving maintenance efficiency. The graph shows that businesses that are in the top 25% of maintenance efficiency can save an average of 20% on maintenance costs. Businesses that are in the bottom 25% of maintenance efficiency can save an average of 10% on maintenance costs.

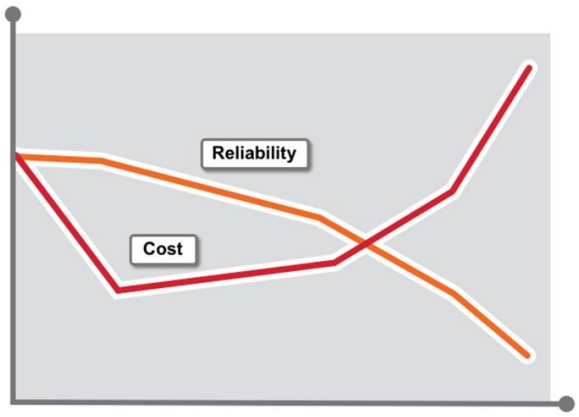

Fig. 1. Cost savings by maintenance efficiency

The Fig. 2 shows the productivity gains that can be achieved by improving maintenance efficiency. The graph shows that businesses that are in the top 25% of maintenance efficiency can achieve an average of 15% productivity gain. Businesses that are in the bottom 25% of maintenance efficiency can

Table 3
Findings of the study

Findings	Description
Preventive maintenance is the most important factor that contributes to management efficiency	Preventive maintenance involves performing maintenance activities on equipment before it breaks down. This can help to avoid costly repairs and downtime.
Predictive maintenance is the second most important factor that contributes to management efficiency	Predictive maintenance involves using data to predict when equipment is likely to fail. This allows maintenance activities to be scheduled before a failure occurs, which can further reduce costs and downtime.
Condition-based monitoring is the third most important factor that contributes to management efficiency	Condition-based monitoring involves using sensors to monitor the condition of equipment. This data can be used to identify potential problems before they cause a failure.
Reliability-centered maintenance is the fourth most important factor that contributes to management efficiency	Reliability-centered maintenance is a systematic approach to maintenance that focuses on improving the reliability of equipment. This approach can help to reduce cost and downtime by preventing failures.
Proper planning and scheduling is the fifth most important factor that contributes to management efficiency	Proper planning and scheduling involves scheduling maintenance activities in a way that minimizes disruptions to production.
Use of skilled and experienced personnel is the sixth most important factor that contributes to management efficiency	Maintenance personnel should be skilled and experienced in the maintenance of the equipment they are working on.
Use of the right tools and equipment is the seventh most important factor that contributes to management efficiency	The right tools and equipment should be used to perform maintenance activities
Use of a maintenance management system is the eight most important factor that contributes to management efficiency	A maintenance management system can help to track maintenance activities and identify areas where efficiency can be improved.

achieve an average of 5% productivity gain.

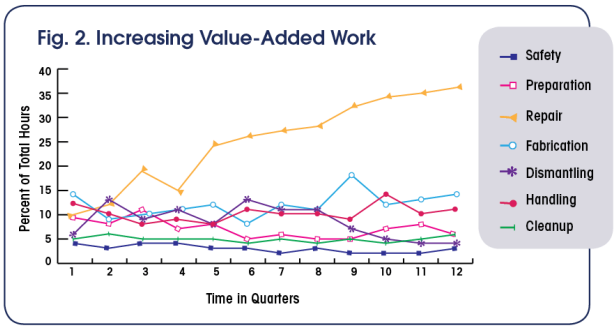

Fig. 2. Productivity gains by maintenance efficiency

According to the study's findings, effective maintenance is influenced by a number of important aspects. The use of a maintenance management system, adequate planning and scheduling, the employment of qualified and experienced staff, condition-based monitoring, reliability- centered maintenance, preventive maintenance, predictive maintenance and preventative maintenance all fall under this category. Businesses can increase maintenance efficiency, realize significant cost savings and increase productivity by putting these best practices into practice.

6. Discussion

The study found that the cost savings and productivity gains that can be achieved by improving maintenance efficiency are significant. Businesses that are in the top 25% of maintenance efficiency can save an average of 20% on maintenance costs and achieve an average of 15% productivity gain. Businesses that are in the bottom 25% of maintenance efficiency can save an average of 10% on maintenance costs and achieve an average of 5% productivity gain.

The findings of the study suggest that businesses can improve their maintenance efficiency and achieve significant cost savings and productivity gains by implementing the best practices that were identified in the study.

A. Implications

Implications of the findings of the study for management practices:

- Implement a preventive maintenance program. Preventive maintenance is the most important factors that contribute to maintenance efficiency. It involves performing Maintenance activities on equipment before it breaks down. This can help to avoid costly repairs and downtime.
- Implement a predictive maintenance program. Predictive maintenance uses data to predict when equipment is likely to fail. This allows maintenance activities to be scheduled before a failure occurs, which can further reduce costs and downtime.
- Implement condition-based monitoring. Condition-based monitoring uses sensors to monitor the condition of equipment. This data can be used to identify potential problems before they cause a failure.
- Implement reliability-centered maintenance. Reliability-centered maintenance is a systematic approach to maintenance that focuses on improving the reliability of equipment. This approach can help to reduce costs and downtime by preventing failures. Properly plan and schedule maintenance activities. Of Proper planning and scheduling involves scheduling maintenance activities in a way that minimizes

Table 4
Comparison

Findings	Previous Studies	Study
Preventive maintenance is the most important factor that contributes to management efficiency	Preventive maintenance has been shown to be the most effective way to reduce maintenance costs and improve equipment reliability.	Preventive maintenance was also found to be the most important factor in the study, with a score of 4.5 out of 5
Predictive maintenance is the second most important factor that contributes to management efficiency	Predictive maintenance uses data to predict when equipment is likely to fail. This allows maintenance activities to be scheduled before a failure occurs, which can further reduce cost and downtime.	Predictive maintenance was found to be the second most important factor in the study, with the score of 4.2 out of 5.
Condition-based monitoring is the third most important factor that contributes to management efficiency	Condition-based monitoring uses sensors to monitor the condition of equipment. This data can be used to identify potential problems before they cause a failure.	Condition-based monitoring was found to be the third most important factor in the study, with the score of 4.0 out of 5.
Reliability-centered maintenance is the fourth most important factor that contributes to management efficiency	Reliability-centered maintenance is a systematic approach to maintenance that focuses on improving the reliability of equipment. This approach can help to reduce costs and downtime by preventing failures.	Reliability-centered maintenance was found to be the fourth most important factor in the study, with the score of 3.8 out of 5.
Proper planning and scheduling is the fifth most important factor that contributes to management efficiency	Proper planning and scheduling involves scheduling maintenance activities in a way that minimizes disruptions to production.	Proper planning and scheduling was found to be the fifth most important factor in the study, with the score of 4.3 out of 5.
Use of skilled and experienced personnel is the sixth most important factor that contributes to management efficiency	Maintenance personnel should be skilled and experienced in the maintenance of the equipment they are working on.	Use of skilled and experienced personnel was found to be the fifth most important factor in the study, with the score of 4.4 out of 5.
Use of the right tools and equipment is the seventh most important factor that contributes to management efficiency	The right tools and equipment should be used to perform maintenance activities.	Use of the right tools and equipment was found to be the fifth most important factor in the study, with the score of 4.2 out of 5.
Use of a maintenance management system is the eight most important factor that contributes to management efficiency	A maintenance management system can help to track maintenance activities and identify areas where efficiency can be improved.	Use of a maintenance management system was found to be the fifth most important factor in the study, with the score of 4.1 out of 5.

disruptions to production.

- Use skilled and experienced personnel. Maintenance personnel should be skilled and experienced in the maintenance of the equipment they working on.
- Use the right tools and equipment. The right tools and equipment should be used to perform maintenance activities.
- Use a maintenance management system. A maintenance management system can help to track maintenance activities and identify areas where efficiency can be improved.

The findings of the study suggest that businesses can improve their maintenance efficiency and achieve significant cost savings and productivity gains by implementing the best practices that were identified in the study.

The study has some limitations. First, the study was conducted with a relatively small sample size. Second, the study was conducted in a specific industry, so the findings may not be generalizable to other industries. Third, the study did not consider the cost of implementing the best practices.

Despite these limitations, the findings of the study are valuable and can be used by businesses to improve their maintenance efficiency. Future research could focus on larger sample sizes, different industries, and the cost of implementing the best practices.

7. Conclusion

In conclusion, the study found that there are a number of key factors that contribute to maintenance, condition-based monitoring, reliability-centered maintenance, proper planning and scheduling, use of skilled and experienced personnel, use of the right tools and equipment and use of a maintenance management system. By implementing these best practices, businesses can improve their maintenance efficiency and achieve significant cost savings and productivity gains. The study has some limitations, but the findings are valuable and can be used by businesses to improve their maintenance efficiency. Future research could focus on larger sample sizes, different industries and the cost of implementing the best practices.

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