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Predictive Maintenance: The New Creator of a Manufacturing Enterprise's Points-of-Difference

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ABSTRACT

Effective use of predictive maintenance creates enormous points-of-difference that bolster a manufacturing firm's competitiveness. However, systematic review indicated that even if the stringent use of an effective predictive equipment maintenance plan creates points-of-difference that bolster a manufacturing firm's competitiveness, empirical evidence still indicated poor management support to be a problem in most manufacturing enterprises. Poor management support often mutates into inadequate resource allocation. This affects the investment in the right technologies, sensors, and software for measuring and alerting management about the failing state of equipment performance. Predictive maintenance is also often affected by poor training to improve skillfulness. Combined with the difficulties of managing and influencing change from a reactive equipment maintenance mindset to a predictive approach, these were found to undermine the overall effectiveness of predictive maintenance.

INTRODUCTION

Increasing competition in the global manufacturing business landscape is driving most of the manufacturing firms to explore various unique ways of operation so as to create advantages that bolster their competitiveness. In such quests, improvement of predictive maintenance is one of the strategies that most manufacturing firms are exploring to gain unique competitive advantages (Luo, Hu, Ye, Zhang, & Wei, 2020). Predictive maintenance eliminates risks of unplanned operational disruptions to improve operational efficiency, productivity, and throughput. This reduces the marginal costs used for making additional product units to lower operational costs. Reduced operational costs create cost advantages that can be passed to customers in the form of lower prices. It is such capabilities that improve cost competitiveness. It creates points-of-difference that bolster a manufacturing enterprise's cost competitiveness (Rabah, Assila, Khouri, Maier, Ababsa, Bourny, Maier, & Merienne, 2021).

The elimination of sudden unplanned machine maintenance also improves quality management. This improves the production of products that respond to quality specifications. Quite often, quality specifications are derived from the analysis of the unfolding customer tastes and preferences. Hence, production and delivery of products that meet quality specifications, or even customer expectations, spurs improved competitiveness. Predictive equipment maintenance connotes the strategic process of evaluating and analysing various manufacturing equipment, machinery, and assets to discern the areas requiring repairs, upgrades, and maintenance before the equipment breaks down (Zonta, da Costa, Righi, de Lima, da Trindade, & Li, 2020).

Predictive maintenance diagnoses the overall effectiveness of the manufacturing equipment and machinery to discern the parts that must be changed, the software that must be upgraded, the old equipment that must be abandoned in favour of new acquisitions, and the equipment that must be repaired to improve the overall operational efficiency. It is through such initiatives that it creates unique advantages that create points-of-difference to spur a firm's improved competitiveness (Aivaliotis, Xanthakis, & Sardelis, 2020). Predictive maintenance aids the analysis and response of the operational managers to problematic areas before the machine or the equipment breaks down to cause a downturn that affects productivity. This eliminates the risks of frequent machine failures that often affect operational efficiency, productivity, and effective cost management. To achieve that, Berrabah, Belkacemi, & Zemmouchi-Ghomari (2022) share similar views that some of the metrics or indicators for measuring the effectiveness of predictive equipment maintenance encompass reliability, availability, performance, quality, efficiency, cost-effectiveness, safety, risks, sustainability, and continuous improvement tests.

Reliability indicator measures if the equipment is constantly operating all the time with minimal disruptions. If so, it also improves the quality of the data to be used. Availability assesses if the equipment is available for use all the time. This improves the performance and the state of equipment utilization (En-Nhaili, Muchiri, & Pintelon, 2021). If the equipment is not being utilized, the management may not achieve the desired ROI. Yet, the equipment is not being used all the time. This aids assessment of redundancy and idle time of the equipment. Efficiency measures the efficient operation of the equipment. It also measures if the planned equipment maintenance is always failing to close the gap between actual and planned maintenance.

Cost-effectiveness is the other indicator for measuring the effectiveness of predictive equipment maintenance. It measures the cost of maintenance against the produced output, as well as the cost of maintenance against the asset value percentage (Berrabah et al., 2022). Cost-effectiveness indicator assesses the cost ratio of planned and unplanned maintenance. If the maintenance causes accidents due to mistakes of the maintenance personnel, it reduces the cost-effectiveness of the maintenance activities. Even during the calculation of ROI of predictive maintenance, the costs incurred in addressing the incidents or accidents may affect the overall ROI of predictive maintenance. To avoid such scenarios, the safety and risk management controls of predictive maintenance are evaluated to test the overall effectiveness of its safety and risk management systems (Rahman et al., 2024). It assesses the level of caution and compliance to ensure predictive maintenance activities are accomplished in a way that prevents accidents, incidents, and all other forms of risks. Such analysis is often integrated with the evaluation of the quality indicator.

Quality indicator measures the rate of defects being produced by the machine. If the defect rate is too high, it means the predictive maintenance is not being effectively done (Berrabah et al., 2022). It means there are errors, poor addressing of the problem, or usage of defective parts during repairs and maintenance. This increases the cost of equipment maintenance to affect the overall ROI of predictive equipment maintenance. Sustainability indicator measures the efficiency and energy consumption rate of the equipment and machinery. If the energy consumption rate is high, it means the predictive equipment maintenance is not doing enough. This often calls for more evaluation and improvement of the approach for predictive equipment maintenance.

Even if that is so, usage of predictive maintenance is not one of the strategies that most manufacturing firms recognize as essential for bolstering a firm's improved competitiveness. Instead, most of the manufacturing firms often opt for the use of reactive maintenance (Yan, Lei, Li, Si, Pintelon, & Dewil, 2022). With reactive maintenance, some operational managers misconstrue that they save money if the management waits for machines to break down and then spend on repairs. Yet, as they adopted the reactive maintenance approach, they never consider the hefty costs of doing repairs that could have been prevented by spending just a small amount on maintenance or minor repairs. To complicate such a problem, most manufacturing executives have often not bothered to evaluate and measure the ROI of the funds spent on predictive maintenance (Baur, Albertelli, & Monno, 2020). Most manufacturing enterprises spend enormously on predictive machine maintenance, but they never go at length to assess the ROI of the expenditures on predictive maintenance. Such business approaches affect the evaluation of whether the business is achieving the desired outcomes from its various expenditures on predictive machine maintenance. It also affects the assessment of whether the expenditures on certain aspects of predictive equipment and machine maintenance are producing the best results or not.

Since ROI analysis is results-driven, it aids the evaluation of the extent to which some aspects of predictive maintenance must be discontinued or enhanced to influence the achievement of the best business results (Booyse, Wilke, & Heyns, 2020). Combined with the other limitations, this affects the use of predictive maintenance in the way that creates enormous points-of-difference to bolster a manufacturing firm's competitiveness. Most studies have not examined much of how predictive maintenance spurs improved competitiveness of the manufacturing enterprises. This creates a gap that this study seeks to explore. Instead, most studies focus on evaluating the values of using predictive versus reactive maintenance, as well as the methods, techniques, and limitations of predictive maintenance. To respond to such a gap, this study uses systematic review as the method for analysing how predictive maintenance creates enormous points-of-difference to improve the competitiveness of the manufacturing enterprise.

METHODOLOGY

Systematic review was used as the methodology for exploring how predictive maintenance creates enormous points-of-difference to improve the competitiveness of the manufacturing enterprise. Systematic review refers to one of the methods for critical content analysis that focuses on evaluating findings of the existing studies to identify the epistemological gap that it can respond to (Ghamrawi et al., 2025). It often reviews and analyses the existing studies in the quest of discerning the answers to the research questions raised by the phenomenon being examined. Just like meta-synthesis, integrative review, and meta-analysis, systematic review connotes one of the critical content analysis methods which is used for conducting studies only in the areas where a lot of studies have been conducted (Lim, 2025). Where a lot of studies have been conducted, it is often believed that it is just through the analysis of the existing studies that the study can respond to the questions raised by the concept being investigated. It is such insights that motivate the use of systematic review in this study.

In this study, a lot of studies have so far been conducted on predictive maintenance's use by the manufacturing enterprises and how to create the competitive advantage of the manufacturing enterprises. But in these studies, only a few studies explore the direct linkage of how predictive maintenance bolsters improved competitiveness of the manufacturing enterprise. It is such a gap that this study sought to explore and address. To achieve that, the process of systematic review was structured according to four steps encompassing formulation of the systematic review questions, literature search, data extraction, and data analysis (Ghamrawi et al., 2025; Lim, 2025). The systematic review question examined:

— ***How does predictive maintenance create enormous points-of-difference to bolster the competitiveness of the manufacturing enterprise?***

After the formulation of the systematic review question, the process of literature analysis and search was guided by the keywords that included "Predictive Maintenance"; "Competitive Advantages Created from Predictive Maintenance"; "Advantages of Predictive Maintenance"; "Values of Predictive Maintenance"; "Limitations of Predictive Maintenance." While guided by these keywords, the process of literature search was accomplished using Google as the major search engine. However, the literature to be extracted had to have been published in English in the period between 2020 and 2025. The articles also had to have full contents, since articles with only the abstracts were excluded even if relevant to the study. Upon the extraction of the desired articles, the process of analysing the extracted articles was accomplished using thematic analysis (Shehata & D'Souza, 2025). Each extracted article was read and re-read with the motive of identifying themes and narratives that explain how predictive maintenance creates enormous points-of-difference to improve the competitiveness of the manufacturing enterprise. From such analysis, the details of the findings are analysed and presented below.

FINDINGS

In response to the research objectives and questions that explored what kinds of predictive maintenance approach would create enormous points-of-difference to spur improved competitiveness of the manufacturing enterprise, findings revealed the critical determinants to encompass:

— Strategic Predictive Maintenance Process
— Strategic Plan for Predictive Equipment Maintenance

Details of these are evaluated as follows.

Strategic Predictive Maintenance Process

Predictive maintenance may require the utilization of four main steps encompassing:

— Data Collection
— Data Analysis
— Pattern Analysis and Recognition
— Taking Actionable Insights

It is difficult to accomplish predictive machine diagnosis and maintenance without effective data collection and analysis. Data collection uses various forms of technologies, sensors, and various connected devices in the analysis and gathering of the desired real-time information (Heim, Clemens, Steck, Basic, Timmons, & Zwiener, 2020). Such real-time information must provide detailed insights about the performance of various manufacturing machines and equipment that the business is utilizing in the accomplishment of its various manufacturing activities. Using cloud computing and big data technologies, the gathered real-time data is often analyzed to enable the operational managers to evaluate and identify the areas of problems (Khan, Farnsworth, McWilliam, & Erkoyuncu, 2020). This could be areas causing quality problems or slow production processes affecting the speed and efficiency of the manufacturing processes. From the detection of such problems, the operational managers are able to dig deeper to find out the areas of the manufacturing equipment or machinery requiring maintenance, upgrade, repair, or complete replacement. It is from such insights that the management is able to take actions and avoid machine failures that can affect operational efficiency (Villa, Naticchia, Bruno, Aliev, Piantanida, & Antonelli, 2021), or even failures that cause downtime and redundancies. While relying on the modern technologies, predictive machine maintenance often consists of four components encompassing:

— Technology
— Data Analytics
— Human
— Organisation

The technology component requires the utilization of all the essential technologies like cloud computing, Internet of Things, blockchain, big data, additive manufacturing, and the required sensors and other connected devices in the accomplishment of the required manufacturing activities. Usage of these technologies improves the efficiency of real-time activities' monitoring and evaluation. It places the entire manufacturing activities online (Luo, Hu, Ye, Zhang, & Wei, 2020). This improves the capabilities of all the required advanced technologies like robotics, artificial intelligence, and machine learning technologies to be used in the evaluation of the state of the performance of various designated manufacturing machinery and equipment.

Data analytics is an important component that requires constant data gathering and analysis to be integrated not only as an important organizational culture, but also as an important aspect of predictive machine maintenance. It is through constant data gathering and analysis that the business is able to constantly evaluate and respond to the problems affecting the overall effective performance of the business (Rabah, Assila, Khouri, Maier, Ababsa, Bourny, Maier, & Merienne, 2021). It is through data gathering and analysis that the business is able to evaluate and detect the areas of the manufacturing machine and equipment requiring repair, upgrade, or even maintenance.

The human component of predictive machine maintenance emphasizes the importance of ensuring that all the employees are trained and skilled to use the available technologies. It requires the development and improvement of the skills and competencies of the existing employees to use all the available technologies in the way that improves the effectiveness of predictive maintenance (Sun, Bao, Li, Zhang, Liu, & Zhou, 2020). It is through effective use of the available technologies that the employees and managers can realize the best outcomes. However, the employees must not only have the skills and competencies to use the available technologies, but also be encouraged to embrace the culture of a higher level of data utilization. Predictive machine maintenance relies highly on data analysis and utilization. Hence, employees must also be encouraged to adopt the culture of constant data analysis and utilization in the accomplishment of various decision-making activities (Keller & Owen, 2025). This improves the effectiveness of predictive maintenance that often relies on the emerging real-time data to make decisions on the maintenance activities that must be accomplished to bolster the business' overall effective performance.

Predictive maintenance is key for enhancing the manufacturing enterprise's overall effective performance. It bolsters the continuity of manufacturing operations. It also lowers the costs of manufacturing operations. As it aids the achievement of such advantages, predictive maintenance also reduces risks of accidents. It improves workplace safety to reduce the costs and disturbances that often arise from accidents that occur during working hours (West, Siddhpura, Evangelista, & Haddad, 2024).

Strategic Plan for Predictive Equipment Maintenance

Implementation of the predictive equipment maintenance programme requires the development and use of a more effective strategic plan. The strategic plan offers insights on the critical activities that must be accomplished for the manufacturing enterprise to get the best out of its predictive equipment's maintenance activities (Zhong, Xia, Zhu, & Duan, 2023). Despite having enormous resources, some manufacturing enterprises often treat predictive maintenance as the process of just buying and installing sensors in different manufacturing equipment and machinery. When these sensors alert management about the need for maintenance, upgrade, or repair, most of the manufacturing enterprises assume that they are using predictive equipment maintenance (Sensemore, 2025). It is true, predictive maintenance starts from the investment in the required technologies. But still, it also exceeds the mere investment in the acquisition and installation of the required technologies and manufacturing machines and equipment. Instead, use of predictive maintenance requires the development and utilization of a more effective strategic plan. The strategic plan often outlines the critical business objectives that must be achieved. Such business objectives could require:

— Improvement of the level of manufacturing assets' optimization
— Improving operational efficiency
— Reducing costs and resource wastage
— Improving productivity and throughput
— Improving quality management, customer service quality
— Competitiveness
— Profitability and returns on shareholders

Contrasted with the situation where there is no strategic plan at all, it is the strategic plan that often guides the evaluation of whether the process for the accomplishment of different predictive equipment maintenance activities is influencing the achievement of the desired goals and objectives (HexaState, 2025). The strategic plan for the predictive equipment maintenance activities acts as the guide that influences decisions on the kinds of required resources, technologies, machinery, and talents. By improving the accuracy of such decisions, the strategic plan for equipment's maintenance bolsters the effectiveness of the predictive equipment maintenance activities to achieve the desired business outcomes. To achieve that, several theories agree with Limble (2025) that the development of the strategic plan for predictive equipment maintenance must flow according to six chronological activities encompassing:

— Step 1: Analysing and Identifying Manufacturing Assets for Predictive Analysis
— Step 2: Collecting and Logging Actionable Data
— Step 3: Analysing Causes and Rate of Equipment Failures
— Step 4: Selecting and Installing Monitoring Equipment
— Step 5: Developing and Introducing Algorithms Predicting Equipment's Failure
— Step 6: Deploying Pilot Equipment

Most theories often start the development of the predictive maintenance plan with the objectives that must be achieved. But Limble (2025) argues that the development of an effective strategic plan for predictive equipment maintenance must start with thorough analysis and identification of the assets that must be placed under the predictive maintenance plan.

— Step 1: Analysing and Identifying Manufacturing Assets for Predictive Analysis

Not all manufacturing assets require the usage of a predictive maintenance plan. Some assets are quite durable and do not fail. Others do not have inbuilt systems for monitoring the state of their performance. Hence, the only way for dealing with them is to allow them to work until they fail or start to show clear signs of the risk of failure. Limble (2025) further argues that placing all manufacturing equipment and machinery on predictive maintenance can be a waste of resources. Putting some manufacturing equipment and machinery on predictive maintenance may require use of a lot of money. It could require abandonment of the machinery or equipment which is still working well. Instead of buying new equipment, it is often better to continue using the equipment until it completely finishes its lifetime value and becomes useless (Moss, 2025).

Even if not all manufacturing equipment and machinery require placement on the predictive maintenance plan, some studies caution that problems may arise from this. Some operational managers may take advantage of such a policy, to remove most of the manufacturing equipment and machinery from the predictive maintenance plan. Indirectly, this can lead to the reversal of the reactive maintenance approach. To make the mistake that they are saving money from unnecessary preventive equipment's maintenance, some managers retain only a few equipment and machinery on the predictive equipment's maintenance plan. This can turn out to be problematic, as most machines that should have been placed on the predictive maintenance plan start to suddenly fail and malfunction to interfere with the normal production activities.

To mitigate risks of such situations, Limble (2025) suggested a combination of criteria that can be used for assessing whether or not to place any equipment on the predictive maintenance plan. The only manufacturing assets that can be placed on the predictive maintenance plan are those that take a lot of financial and non-financial resources to operate. That means their failure can affect the manufacturing enterprise's overall effective performance. Other assets are those that take a lot of repair and spare parts' replacement costs. This means instead of waiting for machine failure to spend a lot of money, periodic repair and maintenance costing just a little money would be more preferable (Ameta, 2024).

In addition, manufacturing equipment and machinery that frequently fail must also be placed on the predictive maintenance plan. Manufacturing equipment and machinery that are core to production must be placed on the predictive maintenance plan. This prevents the kinds of machine failure that renders the entire manufacturing plant redundant. To prevent such incidents and risks, it is often better to plan and do preventive maintenance. Limble (2025) further proposes that manufacturing equipment and machinery that are complicated to repair and take long to repair must also be placed on predictive maintenance to avoid failure that paralyzes the entire manufacturing operations.

Once the manufacturing equipment to be placed or not to be placed on predictive maintenance is determined, the next question deals with the gathering and analysis of all the required information for designing the predictive machine maintenance model.

— Step 2: Collecting and Logging Actionable Data

Collecting and logging actionable data is the strategic process of trying to gather and find out all information about the processes and steps for maintaining the existing equipment. Effective maintenance of the existing equipment requires detailed analysis and evaluation of the information on what needs to be done and the schedules for accomplishing such equipment maintenance activities (Oxmaint, 2025). Without understanding any information about the existing equipment's maintenance, it is difficult to design and accomplish the required equipment maintenance activities.

Predictive equipment maintenance does not wait for the machines to break down. Instead, predictive maintenance often diagnoses the machine to respond by repairing, upgrading, or updating the machines before they fail. For that reason, the maintenance engineers may rely on sensors plugged in or the inbuilt sensors to notify about the impending maintenance schedules. But in some cases, some manufacturing machines do not have sensors (Siemens, 2025). That explains why the management needs a structured process of gathering information so as to accurately understand how different machines must be maintained and according to what kinds of schedules.

To achieve that, the potential sources of information about most of the manufacturing machines are often found from the manufacturers' information, as well as the maintenance engineers' information. Most manufacturing machinery and equipment often come with the manufacturing manual on how to operate and maintain the machines. Information on how to operate the machines can be optimized to avoid mistakes that cause the failure of the machines (Reliable Plant, 2025). The motive of predictive equipment maintenance is to prevent machine failure. And that can be achieved by not only repairing the machines, but also by ensuring that the machines are properly operated and used. Such information also helps ensure that the machine produces the best products.

When it comes to maintenance, the manufacturers often provide critical information on the activities that must be accomplished during the equipment's servicing, upgrade, or update. The manuals from the manufacturers often explain the kinds of required maintenance, the schedules, and how the maintenance is done when it is due (Sankar, 2025). Compliance with the manufacturer's manuals is one of the critical tools for extending the lifespan of the manufacturing machines. From the manufacturers' information, the management can develop the predictive maintenance plan for each manufacturing machine.

In addition to the manufacturers' information, the in-house maintenance engineers are the other critical sources of more important information. In-house maintenance engineers interact with the designated specific manufacturing machines on a daily basis. For that reason, the in-house maintenance engineers often know too much about the behaviours and maintenance schedules for different machines. Sometimes, the in-house engineers even become more creative and innovative to act outside the manufacturers' instructions. To ensure that the machines are running properly, the in-house maintenance engineers could craft a way of identifying problems and servicing the machines before they fail.

When the machines are new, they often have warranties which are used for servicing the machines. But once the warranty periods expire, the manufacturing enterprise is expected to foot the maintenance bills. Quite often, in the long run, different machines may develop different behaviours and different maintenance requirements, which are different from the maintenance instructions provided by the manufacturers. These imply that speaking to and gathering information from the in-house engineers can offer essential insights about the state of the machine's performance, its unique maintenance activities, its unique behaviours, and the required critical maintenance activities. Once all the required data is gathered, the next issue deals with the analysis of the available data to discern the nature and causes of equipment failures.

— Step 3: Analysing Causes and Rate of Equipment Failures

Effective management of equipment to improve the effectiveess of predictive maintenance requires the accurate analysis and understanding of the state of equipment performance and failure. Understanding the state of equipment performance and failure is essential for determining the kinds of the predictive maintenance plan that can be put in place (En-Nhaili, Muchiri, & Pintelon, 2021). It is through the detailed understanding of the nature of equipment failure that the management can discern the amount of resources and technology needed for predictive equipment maintenance. If the management accurately understands the nature of machine failure and the causes, it becomes easier for them to come up with the predictive maintenance plan, resources, and technology for each of the manufacturing equipment.

When the maintenance plan and schedules are quite clear, it also becomes easier to develop the working plan with the suppliers of different spare parts (Veerappan, 2025). It also becomes easier for operational managers to plan and liaise with the suppliers of various spare parts, as well as the contracted maintenance engineers. This ensures the successful execution of the predictive maintenance system to bolster the improved seamless operation of the manufacturing enterprise.

In that process, Limble (2025) suggests the process of analyzing the state of machine failure must focus on evaluating the seriousness of equipment failure as well as the frequency and difficulties of identifying and isolating some equipment failure. As Limble (2025) states, these require the use of nine steps that require listing and describing the normal functions of the designated manufacturing machines, and the evaluation and identification of all the potential failures and causes for each of the manufacturing machines, as well as the impact of each of the machine's failure on manufacturing operations, processes, resources, people, and customers. Such analysis is essential for diagnosing the seriousness of the failure and the damage that occurs if the machine fails (Alfionita & Ikhwanul Alifin, 2023).

To further assess the degree of the machine failure's severity, it is essential for each failure to be ranked from 1 to 10 so as to identify the most severe failure. Besides assessing the frequency of each machine failure, the management must also evaluate and rank, using a scale of 1 to 10, the ease of detecting potential machine failures. If it is difficult, then an effective predictive maintenance plan is required. After ranking, the scores from the ranking must be used for calculating the risk priority number (RPN) for each machine failure. These offer insights on the areas of severity that must be prioritized during the development and implementation of the predictive machine maintenance plan.

Following the identification of the areas of severity, Limble (2025) suggests that the next initiative would require the introduction of more effective monitoring equipment.

— Step 4: Selecting and Installing Monitoring Equipment

Introduction of more effective equipment monitoring falls at the heart of the initiatives for improving the effectiveness of predictive machine maintenance. It is through the equipment monitoring that the maintenance managers are able to realize and recognize that it is time and the schedule for doing the required equipment maintenance. In effect, in this step, Limble (2025) requires the maintenance engineers and managers to list and install all the required sensors. Even for the manufacturing machines that come with the inbuilt sensors, a critical analysis must be undertaken to assess if additional specific sensors or any other mobile monitoring equipment are required. In that process, some of the sensors that can be installed include thermometers, endoscopes, leak detectors, thermal cameras, tachometers, and accelerometers (Sankar, 2025). These sensors can be used for analysing and detecting undesired vibration, infrared thermography, dynamic pressure analysis, lubricant analysis, acoustics testing, and ultrasound testing. Once all the sensors are put in place and activated, the next step requires the development and use of algorithms for predicting equipment failure.

— Step 5: Developing and Introducing Algorithms Predicting Equipment's Failure

The advancement of artificial intelligence and machine learning technologies has improved the effectiveness of predictive maintenance. It aids the automation of the analysis and alerting of management about the impending failure of different machines (Veerappan, 2025). This enables management to prepare and fix the machines before they fail. Even if the machine fails, the management will have been alerted to prepare for any unplanned downtime. But to achieve that, the maintenance engineers must use all the data acquired about each machine's state of performance and frequency of failure to build a model and algorithms that alert management in the event of impending failure (Duarte & Santiago Scarpin, 2023). These may require the use of sensors for condition monitoring, prognostics algorithms that estimate and alert about the remaining time to machine failure, and predictive modelling that uses the available data on the patterns of equipment failure to create and predict the risks of failure. Once the predictive maintenance plan or model has been created, the next step deals with the testing of the plan.

— **Step 6: Deploying Pilot Equipment**

Testing the predictive maintenance plan requires putting the plan into action. This enables management to monitor and improve the effectiveness of the predictive maintenance plan being used. Even if the use of this model improves the effectiveness of predictive maintenance, studies still indicate the processes are affected by lack of skills, resources, and complexity of some equipment repair and maintenance processes (Berrabah, Belkacemi, & Zemmouchi-Ghomari, 2022; Rahman, Sugiono, Sonief, & Novareza, 2024). Even if the stringent use of these processes creates advantages that improve the points-of-difference that bolsters a manufacturing's competitive advantage, empirical evidence still indicates the effective use of predictive maintenance to be affected by poor management support (Veerappan, 2025). Effective use of predictive maintenance is also undermined by inadequate resource allocation. Other limitations often arise from poor investment in the right technologies, sensors, and software for measuring and alerting management about the failing state of equipment performance. Predictive maintenance is also often affected by poor training to improve skillfulness. Combined with the difficulties of managing and influencing change from a reactive equipment maintenance approach to a predictive approach, these undermine the overall effectiveness of predictive maintenance.

CONCLUSION

Predictive maintenance creates points-of-difference that bolster a manufacturing enterprise's cost competitiveness. The elimination of sudden unplanned machine maintenance also improves quality management. This improves the production of products that respond to quality specifications. Quite often, quality specifications are derived from the analysis of the unfolding customer tastes and preferences. Hence, production and delivery of products that meet quality specifications or even customer expectations spur improved competitiveness. Predictive equipment maintenance connotes the strategic process of evaluating and analysing various manufacturing equipment, machinery, and assets to discern the areas requiring repairs, upgrades, and maintenance before the equipment breaks down. Predictive maintenance diagnoses the overall effectiveness of the manufacturing equipment and machinery to discern the parts that must be changed, the software that must be upgraded, the old equipment that must be abandoned in favour of new acquisitions, and the equipment that must be repaired to improve the overall operational efficiency. It is through such initiatives that it creates unique advantages that create points-of-differences to spur a firm's improved competitiveness. But to achieve that, findings imply that the use of an appropriate strategic predictive equipment maintenance plan is essential for the manufacturing enterprises to achieve the best business outcomes.

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