Assessment of Maintenance Performance Using the Maintenance Scorecard Method and Prioritization of Problem Control Strategies with the USG Method

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Abstract*— Measuring the performance of machine maintenance becomes very important, serves as a monitoring tool, and triggers increased performance in the production section. Losses due to engine damage will impact the company's profit, which is less than optimal because maintenance can contribute as much as 20-50% of the cost composition of the company's operational costs. This study aimed to measure performance in the maintenance section using the maintenance scorecard (MS) and determine the priority of the performance control strategy using the Urgency, Seriousness, and Growth Method (USG). The research was conducted through case studies on chemical manufacturing companies located in Indonesia. The performance assessment results with the maintenance scorecard method show that the total scorecard maintenance value is in the category of need improvement, which is 63.35. There are 3 KPIs in the very bad category: maintenance costs from a cost-efficiency perspective, work completed from a quality perspective, and self-audit from a learning perspective. The first and foremost strategy that can be done based on USG's priority is to implement reliability-centered maintenance (RCM) to reduce time loss and increase the knowledge and competence of employees. This priority is useful when a company encounters a constraint so that it cannot carry out all strategies simultaneously or can only carry out some strategies while still getting optimal benefits from continuous improvement.

***Keywords*—Maintenance management; maintenance scorecard; USG; prioritize strategy.**

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I. INTRODUCTION

Performance is a description of the level of success in implementing policies to achieve the organization's goals, mission, and vision stated in the organization's work plan and also able to control improvement initiatives [1]. In short, the performance level of organizational goals can be interpreted as the extent to which the organization can achieve the goals that have been set. Company performance is what the company achieves concerning established criteria within a specified period [2]. Corporate performance evaluation means a process or system for realizing a company (organization) that is comfortable working based on specific criteria [3]. Performance appraisal is a periodic check carried out on an organization's operational effectiveness or part of it and its employees based on predetermined targets.

Most companies have a goal to maximize the wealth of shareholders or investors. A company's financial performance must be measured to determine its success in achieving these goals [4]. Publicly traded companies are funded by investors, so performance measurement is crucial. Performance measurement is essential for public companies because they are companies with capital from investors. As a public company, the company's performance is no longer solely attributed to the parties within the company but also to the investors. To cover the risks that investors must bear due to investing in risky portfolios, the rate of return that the company must generate must be higher to cover the risks borne [5]. In this condition, companies must be able to compete not only in the trading market but also in the capital market; otherwise, investors will be left behind. In this regard, the need for performance measurement that considers the interests and expectations of investors is an essential requirement. Company success measures help assess activities' achievement relative to company goals [6]. Implementing the company's strategy makes performance measurement very important, which can be used as a benchmark in knowing the success of the company's strategy [7].

In the manufacturing industry, performance measurement is carried out on all aspects of production activities and their supporting parts. To support the company's assets, the mechanical maintenance section requires performance measurement to control the production system's failure risk. The machine maintenance performance measurement section is needed to recognize and control aspects of success, including safety, productivity, cost-effectiveness, environment, quality, and learning perspectives [8]. Comprehensive indicators and methods or procedures are needed to assess asset and machine maintenance performance. Losses due to engine damage will have an impact on the organization's profit, which is less than optimal because maintenance can contribute as much as 20-50% of the cost of the company's operational cost composition, which depends on the level of the mechanism within the company [9]. Measuring the performance of machine maintenance functions is used as a monitoring tool and triggers increased performance in the production department [8].

Maintenance is closely related to engine performance and performance. Proper maintenance can extend the useful life of assets, ensure optimal device availability installed for Production, maximize the return on investment, keep all the equipment operational, and ensure the safety of those who use these facilities. Maintenance is defined as a combination of all technical and administrative actions, including controls, which are performed to maintain an item or to make the item perform the desired function [10].

After the performance measurement is carried out, a strategy is set to control any potential underperformance. This strategy is prepared and developed based on aspects and indicators of organizational performance so that all potential risks in the machine maintenance and maintenance department can be controlled. In certain conditions, companies experience obstacles and difficulties when they have to implement all the strategies that have been prepared, such as financial aspects, human resources, and the inability to control the company's external factors. In this particular condition, prioritize the implementation of the developed strategy. Optimized machine maintenance priority increases overall performance through system placement, using the value of machines being critical to understanding bottlenecks and detecting where they are in the system [9].

There are quite a number of methods for measuring maintenance performance. In previous studies, maintenance performance activities were carried out using the Resilience Importance Measure (RIM) method, which was applied to evaluate the performance of the primary coolant system [11], functional and structural performance measurement method [12], and multi-attribute decision-making (MADM) [13]. Meanwhile, the predictive maintenance approach can be carried out based on manual diagnostics, Failure Mode and Effects Analysis (FMEA), Machine Learning and Forecasting (MLF), Real-Time Sensors (RTS) [14] and Deep Learning (RL) [15]. Another method that is often used is the maintenance scorecard method (MS) [16], [17]. This method is considered good because it considers all aspects of measuring maintenance performance, including productivity, cost-effectiveness, quality, safety, environmental, and learning perspectives [16], [17]. However, this method does not provide a way to prioritize implementing all the resulting strategies. So, in this paper, the MS method is combined with the Urgency, Seriousness, and Growth Method (USG) to assess the sequence of priorities in carrying out organizational strategy. This study aims to measure performance in the maintenance section using a maintenance scorecard (MS) and determine the priority of performance control strategies with USG.

II. Materials and Method

This study uses the maintenance scorecard method to assess maintenance performance, including safety, productivity, cost-effectiveness, environment, quality, and learning perspectives. In the next stage, strategies are developed to control potential failures from each analyzed perspective. Meanwhile, in the final stage, the implementation of control strategies is prioritized using the Urgency, Seriousness, and Growth Method (USG) methods. Primary data retrieval is done by interview method with a questionnaire tool. The research was conducted through a case study of a chemical product company located in Tangerang, Indonesia. This company is a large industrial type with a total of 750 employees. Respondents who became the research sample were the head of the equipment and machine maintenance section.

A. Maintenance Scorecard

Maintenance Scorecard (MSC) is an approach designed to assist the development of implementation strategies in asset management. This is implemented through a hierarchy of objectives or structural approaches into three main levels: corporate, strategic, and functional [18]. The Maintenance Scorecard is a derivative of the balanced scorecard (BSC). Generally, BSC is developed by profit-oriented companies or organizations [19]. The BSC identifies key performance areas (or strategic themes) and key performance indicators or institutional perspectives.

MSC is applied through a hierarchy of objectives or a structured approach consisting of a chain of objectives through three fundamental levels, namely, corporate, strategic, and functional. 6 performance indicators are using the maintenance scorecard approach, as follows:

- Productivity perspective: contributing asset management to the ability to earn more.
- Cost efficiency: reducing unit costs in asset management efforts.
- Quality: ensuring repetition of physical asset performance does not occur.
- Safety: ensuring the company's work on safety incidents tolerable.
- Environment: ensuring the company's exposure to environmental incidents tolerable.
- Learning: staying innovative and using asset management as a growth area [20].

This study juxtaposes six aspects of MS to assess maintenance performance, as shown in Table 1.

TABLE I
QUESTIONNAIRE OF MAINTENANCE SCORECARD PERSPECTIVE

Which criterion do you think is more important in calculating the score on the maintenance scorecard as a technician's performance																		
Criterion A	< A is more important than B									B is more important than A >								Criterion B
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Safety																		Productivity
																		Learning
																		Quality
																		Cost
																		Environment
Productivity																		Learning
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Cost																		Environment

B. *Pairwise Comparison*

A pairwise comparison technique was used to assign weights to each perspective to calculate the priority of the six maintenance scorecard perspectives. Pairwise comparison techniques are widely used to address the subjective and objective assessment of qualitative and/or quantitative criteria in multi-criteria decision-making (MCDM), especially analytical hierarchical processes (AHP) and analytical network processes (ANP) and shown as a Matrix Pairwise Comparison (PCM). AHP allows for weighting criteria with a single score for overall problem evaluation [21]. This method was done by distributing a questionnaire to 3 experts to weigh each perspective. The following is a pairwise comparison questionnaire used.

C. *Urgency, Seriousness, and Growth Method (USG)*

The USG (Urgency, Seriousness, and Growth) method is one method for determining the priority of several possible alternatives in terms of importance, seriousness, and growth [22]. Prioritizing multiple possibilities is an important part of problem-solving [23]. First, due to the limited resources available and the impossibility of solving all problems. Second, because there may be a courting between one trouble and any other [24].

The use of the USG matrix determines a priority condition by setting a rating scale of 1-5 on each aspect; then, the aspect with the highest total score is determined as a priority issue [25]. Qualitative data requires further processing using a scale of importance, and the scale most often used to change the data is the Likert interval scale [26], [27]. The ultrasound matrix result (Table 2) combines values of three comparison elements and sorts according to the number with the largest value due to priority. Explanation of aspects in ultrasound, as follows:

- Urgency: organizational strategies need to be applied to solve problems, related to time availability
- Seriousness: organizational strategies need to be applied concerning the seriousness or gravity of a problem
- Growth: organizational strategies need to be implemented to prevent the possibility that the problem or issue can develop further if not addressed or can cause other problems [28].

TABLE II
ULTRASOUND ASSESSMENT LIKERT SCALE

Scale	Statement
1	Very unimportant
2	Not important
3	Neutral
4	Important
5	Very important

Source: [24]

III. RESULTS AND DISCUSSION

A. *Performance Assessment of Maintenance*

Performance assessment of the maintenance section is carried out on six perspectives of the Maintenance Scorecard: safety, productivity, quality, cost, environment, and learning. At the initial stage, each perspective was weighed by filling out a questionnaire by three experts' lecturer in Industrial Engineering, University of Indonesia. The contents of the questionnaire and the combined weight of the experts were then calculated using the Experts' Choice software. Each response that a respondent gives in the AHP comparison must be tested for consistency to ensure that the response is consistent and reliable. The upper limit of acceptable discrepancies should not exceed 10% [19]. From the three experts, the inconsistency value was 3%, which means that the expert opinion is acceptable. The combined results of experts obtained the order of priority from the six perspectives of the Maintenance Scorecard, as shown in Table 3.

TABLE III

RESULTS OF WEIGHTING MAINTENANCE SCORECARD PERSPECTIVE

No	Perspective	Weight
1.	Safety	40%
2.	Productivity	22,2%
3.	Learning	2,5%
4.	Quality	16%
5.	Cost	8,4%
6.	Environment	8,4%

Safety is a sense of security that the operator has while working. There is no need to worry that the machine used will be disturbed and damaged [29]. Safety is paramount in an industry, and much effort has been put into reducing failures, particularly concerning maintenance against accidents and incidents [30]. Safety is the main aspect and has the greatest weight because it is the basic need of workers in carrying out their work [31]. The operator can work optimally without fear and worry if you have a sense of security and safety. However, many organizations fall short of the ambitious goal of ensuring operations while simultaneously achieving high levels of reliability and security [32]. For organizational leaders, the safety and health aspect is an investment in organizational resources, using a close-knit approach from all employees, which can provide several distinct advantages over the more conventional top-down approach [33]. Maintenance is also responsible for the safety of technical systems and keeping the system in good condition [34].

If the conditions of operator safety and security can be met, it can affect the productivity and efficiency of the work unit. The required production volume is achieved through high availability. This affects equipment reliability and maintenance, as well as the carrying capacity of the maintenance [35]. Production productivity, one of which comes from the level of worker productivity [3]. Productivity from the aspect of quality, quantity, and safety affects the income and profits of the organization [19]. The quality aspect is influenced by many factors, both internal and external to the company [36], and impacts on effectiveness, efficiency, customer satisfaction, and safety [37].

B. *Maintenance Scorecard*

Before analyzing the maintenance scorecard, it is necessary to determine the organization's Key Performance Indicators (KPI). KPIs are the most critical financial or non-financial parameters to determine and measure progress towards targets in current and future conditions in an organization [38]. KPIs are useful decision-making tools because they can make it easier for organizations or companies to measure individual performance and help evaluate the organization's performance to achieve the goals of its strategic vision [39]. Organizational KPI data based on perspective are presented in Table 4.

TABLE IV

KPIS BASED ON THE MAINTENANCE SCORECARD PERSPECTIVE

Perspective	KPI	Unit	Target
Productivity	Lost Time	Minute	361
	Critical Damage	Time	3
Cost	Maintenance cost	USD/Ton Paper	13,86
Quality	Percentage of Work Completed	%	≥89
Safety	Events with lost time	Time	0
	Events without losing time		
Environment	Liquid Waste Quality	%	100
Learning	Root Cause Analysis	%	100
	Self-Audit		90

Based on the weighting results using pairwise comparison, the values obtained from each perspective as well as the overall value of the maintenance scorecard. The results of the maintenance scorecard analysis are presented in Table 5.

TABLE V

MAINTENANCE SCORECARD

No	Perspective	Weight	Strategic target	Score	Total weight
1.	Safety	20%	Events with lost time	100	20.00
		20%	Events without losing time	80	16.00
2.	Productivity	11.1%	Lost time	40	4.44
		11.1%	Critical damage	90	9.99
3.	Learning	2.5%	Root cause analysis	100	2.50
		2.5%	Self-audit	20	0.50
4.	Quality	16%	Completed work	20	3.20
5.	Cost	8.4%	Maintenance cost	20	1.68
6.	Environment	8.4%	Waste quality	60	5.04
Total		100%	Total MSC score		63.35

Based on the results and information from the Maintenance Scorecard (Table 6), the total value of the Maintenance Scorecard is in the Need Improvement category, which is 63.35. There are 3 KPIs in the very bad category: maintenance costs from a cost-efficiency perspective, work completed from a quality perspective, and self-audit from a learning perspective. 1 KPI is in a bad category, namely lost time from a productivity perspective, and 1 KPI requires improvement, namely waste quality from an environmental perspective.

TABLE VI

RANGE OF SCORES FOR MAINTENANCE SCORECARD

No	Score	Information
1.	86 – 100	Very good
2.	71 – 85	Good
3.	56 – 70	Need improvement
4.	40 – 55	Bad
5.	< 40	Very bad

C. *TOWS Matrix*

Based on maintenance scorecard calculations, PT.X is still in the category of needing improvement. To formulate several improvement strategies, the author makes a TOWS Matrix containing the previously identified companies' SWOT. The following is a strategy formulation based on the TOWS Matrix which is presented in Figure 1.

Based on the TOWS Matrix, there are five strategies for each improvement, namely:

- Implementing Reliability Centered Maintenance (RCM) to reduce Time Loss
- Make a regular schedule every month to conduct a self-audit.

- Leveling the competence of technicians with training, report cards, and periodic competency tests
- Create strategic targets that refer to the SMART-defined environmental perspective.
- Implement an RCM framework with a list of possible spare parts to help with future budgeting.

The application of RCM is used to reduce the potential and occurrence of lost time during the maintenance process and is beneficial to the entire running process by minimizing the effects of process disturbances[40]. Appropriate, effective, and regular audits are used to find discrepancies in the running processes [41], including fixing them [42]. Increasing the knowledge and competence of employees is used to adjust the development of science and technology, increase innovation, and improve the ability of employees to adapt to competition and competitiveness [43]–[45].

	STRENGTH	WEAKNESS
	Openess to change and improvement; have excellent teamwork; high responsiveness to work	Technical competence is not evenly distributed; Work is interrupted when the server is down; Workload exceeds the number of technicians; Technicians who do not understand SAP; Do not have strategic targets that refer to the environment
OPPORTUNITY	S-O	W-O
Management system has been integrated with ERP system; Periodic internal training program with experienced teachers	Improve performance by implementing new knowledge (reability centered maintenance; Develop a database of training materials that can be accessed by all technicians	Conduct internal SAP training, so that all technicians are able to operate SAP; Implementation of report system with reward and punishment for technician performance; Conduct maintenance training to level the competence of technicians; Developing strategic targets that refer to the environment, such as the percentage of B3 waste generated
THREAT	S-T	W-T
AM3 section staff number policy; Limited budget availability to hire experts	Conduct periodic technical competency tests to ensure the quality of technician performance	Conduct internal training with existing resources in the team, for example with peer training

Fig. 1 TOWS Matrix

D. Analysis of Urgency, Seriousness, and Growth Method (USG)

In special conditions, the organization faces obstacles in carrying out or implementing strategies to mitigate risks that may occur. This special condition can occur due to internal factors such as financial aspects, availability of human resources, availability of equipment, and others. At the same time, external factors can occur due to several things, such as political and economic conditions, regulation changes, business competition, and others. In this special condition, it is necessary to prioritize the implementation of the strategy by making a priority scale order. In the previous discussion, five strategies have been analyzed and determined. At this stage, an analysis is carried out to make a priority order so that the process of managing potential failures or risks in maintenance goes well. The strategy priority analysis stage uses the USG method by assessing the consequences of the level of urgency (U), seriousness (S), and growth (G) of each strategy that has been determined. The assessment is carried out using the rating values presented in Table 2 as a guide for conducting the assessment. The selection and use of the right strategy will relate to product quality and competitiveness[46].

TABLE VII
CALCULATION OF STRATEGY PRIORITY

No	Strategy	Consequences of possible strategy failure	U	S	G	USG
1.	Implementing Reliability-Centered Maintenance to reduce Time Loss	If lost time is not controlled, it will reduce efficiency and productivity.	5	5	5	15
2.	Make a regular schedule every month to conduct a self-audit	There is no increase in employee competence, and they cannot adapt to competition.	4	3	3	10
3.	Leveling the competence of technicians with training, report cards, and periodic competency tests	Allows competency gaps between employees; competencies are not evenly distributed among all employees.	5	4	5	14
4.	Create strategic goals that refer to the SMART-defined environmental perspective.	Organizations that do not have a clear direction will find it challenging to develop organizational strategies because the vision and mission are unclear.	4	4	3	11
5.	Implement an RCM framework with a list of possible spare parts to help with future budgeting	Allows over budgeting, excess spare parts, inefficient and effective in spare part management	4	4	4	12

Based on Table 7, applying a Reliability-centered Maintenance (RCM) framework and providing training are the most recommended initial strategies. RCM is a systematic approach to assessing the availability of integrated devices and resources and achieving an appropriate level of device reliability, which is expected to be cost-effective. RCM recognizes that every device in a facility has different concerns regarding both process and plant safety [47]. Previous research conducted a Failure Modes and Effects Analysis (FMEA) analysis of the failure mode, identification of the cause of failure, and the effect on equipment failure was obtained to overcome the highest risk. After the highest failure is identified based on risk evaluation, the failure is eliminated using the Reliability Centered Maintenance (RCM) approach [48]. The contribution of training to maintenance performance needs to be made to obtain strategic benefits to meet the challenges posed by global competition. There is empirical evidence that training significantly and positively contributes to maintenance performance in terms of efficiency and effectiveness of maintenance processes [19]. The reliability of the entire system starts from the reliability of the main engine, which is properly maintained [49]. Proper maintenance programs for production systems can improve system reliability and product quality if quality requirements are fully and explicitly integrated into preventive maintenance decision-making [50],[51]. Increasing the level of maintenance leads to a reduction in quality-related impacts, but if the cost of implementing PM is high to the point where quality improvements do not match it, then implementing PM is less beneficial [52].

IV. Conclusion

The performance assessment results using the maintenance scorecard method show that there are five perspectives that need to be improved or followed up immediately, namely the perspectives of productivity, learning, quality, cost, and environment. The Maintenance Scorecard's total value is in the need improvement category, which is 63.35. There are 3 KPIs in the very bad category: maintenance costs from a cost-efficiency perspective, work completed from a quality perspective, and self-audit from a learning perspective. The first and foremost strategy that can be done based on ultrasound priority is to implement reliability-centered maintenance to reduce time loss.

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