Analysis of Maintenance Management Systems in Steel Manufacturing Industry

Fauzia Ashwin Hadits, Giri Aji Anggoro and Hafizh Rifqi
Department of Industrial Engineering
Faculty of Engineering
Universitas Indonesia
Depok, Indonesia
fauzia.ashwin@ui.ac.id; giri.aji11@ui.ac.id; hafizh.rifqi11@ui.ac.id

Abstract

Fierce competition between organizations in this industry 4.0 era has sparked the needs for organizations to gain and maintain their competitive advantage. Incapability of implementing business strategies could result in losing competitive advantage. Maintenance activity has proven to be one of the activities that organizations could benefit from. Maintenance activity is divided into two types in general. Corrective Maintenance (CM) and Preventive Maintenance (PM). To improve the reliability and quality of the system and their component PM is an essential strategy for an organization to be implemented. In this research, a quantitative method was implemented through questionnaires that were distributed in one of the biggest steel manufacturing companies in Indonesia to analyze an organization's condition in conducting maintenance management systems according to Preventive Maintenance Characteristics in the manufacturing industry. Results showed that each PM Characteristic is important in implementing and improving PM Activities.

Keywords
Maintenance Management, Manufacturing and Steel Industry.

1. Introduction

In this industry 4.0 era where competition between producers is very complex to meet consumer needs and attract new consumers. A wide variety of strategies are used by organizations in order to maintain their competitive advantages. The business strategies set by an organization must be able to bring the organization to continue to grow and dominate the market. Incapability to implement business strategies can make organizations lose their competitive advantage to survive in current market competition. Maintenance activity is one of the policies set by the organization as the key in maintaining long-term profitability by prioritizing training for workers to achieve good organizational performance (Fatoni and Nurcahyo 2018). Optimization in industries related to preventive maintenance and production scheduling is useful for increasing efficiency in production, optimizing periodic replacement of parts and meeting distributor demands (Nurcahyo 2016).

In general, maintenance activities are divided into two types, namely preventive maintenance, which is conducted before a failure is detected (Au-Yong et al. 2014). Then the second one is corrective activity that is conducted after a failure is detected. As for preventive maintenance, there are also activities as follows, detection of failures, diagnosis of decreased function of machines and facilities, as well as repairs with the objective of prevention (Au-Yong et al. 2014 and Basri 2017). For a wider scope, maintenance activities are divided into two types of characteristics. The first is a maintenance in which there is a change in the intrinsic dependent character and the second is maintenance without any changes of intrinsic dependent character. The second character mentioned earlier is further divided into two, namely preventive maintenance and corrective maintenance. For preventive maintenance activities, there are two types of maintenance based on the condition of the system, namely predetermined maintenance for maintenance activities without any decrease in the function of the observed machine and condition-based maintenance if a decrease in the function of the observed system is found.

Less optimal preventive *maintenance activities* are a problem that implies a lack of performance in maintenance activities. Preventive maintenance is a type of effective approach to improve the reliability and quality of the system

and its components (Au-Yong et al. 2014). Therefore, *preventive* maintenance needs to be carried out to reduce the need to carry out corrective activities. Generally, preventive maintenance is divided into two strategies, which are scheduled maintenance and condition-based maintenance (Au-Yong et al. 2014). It is recommended for companies to be able to implement and prioritize both maintenance strategies instead of just using corrective maintenance, to be able to achieve optimal maintenance performance.

Maintenance activity in the steel industry might differ from other manufacturing industries. The steel industry, often considered as a mother industry, plays an important role in economic development (Ghogherdchian et al. 2015). Steel products are used mainly in the construction sector and industrial production, which is the main driver of the economy (Long et al., 2016). As a typical processing industry, the steel industry turns iron ore and other ferrous materials into finished products through a series of unit processes, including ironmaking, steelmaking, and rolling process. All production processes cannot be separated from different equipment, that is one of the most important production factors of steel companies. However, the equipment is often used in harsh environments such as extreme temperature, high load, corrosive, abrasive, etc. (Qin et al. 2022). Working for a long time in such a harsh environment will inevitably degrade equipment performance or suddenly fail, product quality fluctuates, even scrap, endangering workers' lives. cause great economic loss to the company (Tecchio et al. 2019; Gao et al. 2020; Kardovskyi et al., 2021). Therefore, it is very important to monitor the maintenance activity to ensure that all the equipment in the steel company can provide a durable production service.

Several studies and surveys have been conducted regarding the maintenance characteristics of several industries and organizations. Au Yong et al. (2014) analyzed maintenance characteristics in office buildings. Chua et al. (2018) studied maintenance characteristics in high residential buildings. Putri et al. (2022) took maintenance in hospital as the object. Setyoko et al. (2022) analyzed maintenance management systems in primary school. Salsabila et al (2022) conducted a survey of maintenance management in convenience stores. Erliza et al. (2022) also conducted a survey in the laboratory, while Kartiko et al. (2022) took a diesel power generator as the object. Putra et al. (2022) studied implementation of maintenance management in the manufacturing industry, but in chemical, pharmacy, tire, and fishing gear industries. This paper aims to analyze maintenance management on steel industries as steel industries' equipment and production lines have different properties compared to other industries.

1.1 Objectives

The objective of this research is to analyze an organization's condition in conducting maintenance management systems according to Preventive Maintenance Characteristics in the manufacturing industry. This research will be carried out to 3 plants of a Steel Manufacturing Company. Furthermore, this research' objective is to formulate which PM Characteristics that are suited the most for manufacturing industry implementation.

2. Literature Review

2.1 Maintenance

Maintenance is a combination of activities, technical, administrative, and managerial from planning to implementation based on the life cycle of an object, workplace, work equipment, or means of transportation to maintain and maintain the value of an asset (Al-Turki et al. 2014). With the development of industry and technology that makes consumer demand and needs more complicated, a company in both manufacturing and services needs to pay attention to the maintenance aspect of the availability and reliability of its manufacturing assets. Availability refers to the readiness of the equipment to operate and produce while reliability refers to the ability of the equipment to function at any point in time (Ben-Daya 2009). This must be done because the equipment or machine is very important and needs to be used on an ongoing basis given that equipment breakdowns can be anticipated before they experience greater damage and make an easier supply of spare parts (Sahli 2021).

Maintenance makes an important contribution to the usage of equipment in the organization. Each maintenance management is responsible for determining its maintenance strategy (BSI 2017). In implementing good maintenance performance management, it is necessary to integrate business factors as a determinant of the success of the overall organizational strategy (Tsang et al. 1999). According to Al-Turki et al. (2014), Maintenance in a manufacturing industry is one of the most complex types of maintenance compared to construction, transportation and service businesses. Manufacturing is becoming very competitive with very high pressures associated with highly technical equipment that requires specialized expertise in reducing costs and increasing asset value and product quality.

2.2 Preventive Maintenance

Preventive Maintenance (PM) was introduced in the 1950s as a fixed time scheduled planning technique used in industry with the aim of achieving an effective maintenance system to detect, prevent potential failures, improve reliability, quality of the system and its components, and extend the life of the equipment in working order become a good condition (Ahmad 2021; Au Yong et al. 2014; Chua et al. 2018; Basri 2017). Preventive Maintenance must be planned and carried out in a very careful manner to avoid damage to equipment or nearby equipment during inspection, repair, adjustment or installation and reassembly of spare parts. (Al-Turki et al. 2014). In the implementation of Preventive Maintenance, a company must be able to determine when maintenance activities should be carried out because the process is in the form of identifying and handling problems before they become critical (Eti et al. 2006). Preventive Maintenance is important because the cost of preventive maintenance will be smaller than the cost of failure due to the need for unexpected and extensive maintenance resources (Au Yong et al. 2014).

2.3 Characteristics of Maintenance

Maintenance management, it is necessary to pay attention to the characteristics that can affect the overall maintenance performance to be effective and efficient (Au Yong et al. 2014). We identified the characteristics in this study from several literatures, including:

Skill and Knowledge of Maintenance Labor

Skilled workers are one of the important factors in PM because this work is carried out in fixed and consistent time intervals. Details that need to be considered are: allocation of costs, skills and knowledge, number of workers, and a Maintenance Manager is also needed to coordinate management and coordinate all activities (Au Yong et al. 2014; Chua et al. 2018; Basri 2017; Van Horenbeek 2013). The effectiveness of the maintenance program will be influenced by the expertise and skills of a maintenance personnel and can have an impact on program performance (Setyoko 2022).

Spare parts and Materials

Management of materials and spare parts is an important aspect of maintenance because there is a need for availability if there are machines / tools that are damaged. So, it needs to be managed in supply, inventory, and storage of spare parts. Details that need to be considered are the allocation of costs, quality, and stock level of spare parts. If no spare parts are available, maintenance will be delayed and high downtime is likely to occur (Au Yong et al. 2014; Chua et al. 2018; Van Horenbeek 2013).

Planned Interval for Maintenance

Maintenance intervals have an impact on maintenance results. This is because preventive maintenance is performed at fixed intervals to reduce the risk of future failures. Details that need to be considered are the allocation of costs and the duration of the work interval (Au Yong et al. 2014; Chua et al. 2018; Basri 2017). Preventive maintenance carried out at fixed intervals to achieve minimal breakdowns in the future (Setyoko et al. 2022).

Failure and Maintenance Downtime

Downtime involves the time required to detect, repair or replace and restart the system. Usually the system experiences downtime on maintenance activities, component failures, inspections, and material shortages. Details that need to be considered are the allocation of costs, the amount of downtime, and how to determine failure and downtime in a period (Au Yong 2014; Chua 2018; Basri 2017).

Maintenance Equipment and Technique

Maintenance activities that include repair, replacement and inspection using certain techniques according to the type of machine and damage and computational costs are required using technology (Au Yong, 2014; Basri, 2017). Comprehensive equipment maintenance is a process carried out to keep it operating properly. Proper procedures can also help maintain work productivity and prevent work accidents (Setyoko 2022).

Acquisition of Maintenance Data

The maintenance report is a document that provides information about maintenance operations in the previous period and the results carried out. So that the data in the report can be used as a reference and guide for maintenance

needs. The recording of maintenance data and documentation accurately is important in improving the quality of maintenance and otherwise maintenance will be hampered if the data collection is not handled properly. (Au Yong 2014 and Murthy et al., 2015).

Financial Aspect

Budget availability is one of the priorities in allocating most of the maintenance budget for critical machines or equipment that need maintenance in order to ensure the continuity of the production process. Records or historical data on budget usage are needed in monitoring maintenance costs so that over-budget does not occur (Putra et al. 2022).

3. Methods

Descriptive statistical research is used in this study, through a qualitative survey that was conducted in Steel Manufacturer consisting of several separated production lines, from iron making to rolling mills. The survey was built from 13 questions that developed based on the literature review on the characteristics of preventive maintenance, as shown in Table 1. The total number of respondents is 30, who came from various production lines and sub-division.

Tabel 1. List of Questionnaires

Code	Question
P1	How long does it take for a technician to gain expertise as a PM personnel?
	(1= 0 - 1 years; 2= 1 - 3 years; 3= 3 - 5 years; 4= 5 - 10 years; 5= more than 10 years)
P2	How many years of experience does each PM personnel in your company have?
	(1= 0 - 1 years; 2= 1 - 3 years; 3= 3 - 5 years; 4= 5 - 10 years; 5= more than 10 years)
P3	How influential is the formal academic degree of PM personnel to PM quality?
	(Very not influential 1 2 3 4 5 Very influential)
P4	How big is the impact of working experience of a PM personnel to PM quality?
	(Very not influential 1 2 3 4 5 Very influential)
P5	How important is it for a factory to have a storage for keeping its spare parts?
	(Very not important 1 2 3 4 5 Very important)
P6	Is the availability of consumable and spare parts in your working area sufficient?
	(Very not sufficient 1 2 3 4 5 Very sufficient)
P7	Which one is more influential in scheduling a PM interval, is it based on manufacturer recommendation or PM personnel' experience?
	(Manufacturer recommendation 1 2 3 4 5 PM personnel' experience)
P8	How important is it to adhere to the PM interval based on manufacturer recommendation?
	(Very not important 1 2 3 4 5 Very important)
P9	How important is it to adhere to the PM interval based on PM personnel' experience?
	(Very not important 1 2 3 4 5 Very important)
P10	How big is the impact of frequent PM and PM measures conducted in reducing downtime at your workplace?
	(Very not influential 1 2 3 4 5 Very influential)
P11	Are your tools sufficient for PM activities?
	(Very not sufficient 1 2 3 4 5 Very sufficient)
P12	How often the post-inspection and maintenance are used in improving maintenance quality?
	(Rarely used 1 2 3 4 5 Frequently used)
P13	Is the budget allocated for maintenance sufficient for consumables, spare parts, machine renewal, machine overhaul, tools procurement, and maintenance personnel?
	(Very not sufficient 1 2 3 4 5 Very sufficient)

4. Data Collection

A total of 30 respondents from the steel industry were involved to assess maintenance management in their workplace. There are the answers that have been collected in Tabel 2.

Tabel 2. Respondents' Questionnaire Assessment

Respondent	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
R1	1	5	3	5	3	3	3	3	4	4	5	3	5
R2	3	4	3	3	5	3	3	5	5	4	3	5	2
R3	3	5	4	4	5	2	2	4	3	4	3	5	2
R4	3	3	4	4	5	3	2	4	4	5	3	4	2
R5	2	4	2	5	5	2	4	3	4	5	4	4	2
R6	2	3	3	3	3	3	5	3	4	4	3	3	3
R7	2	1	3	4	3	3	3	3	3	5	3	4	4
R8	4	2	4	5	3	3	4	4	3	4	4	5	3
Respondent	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**	**P13**
R9	3	3	3	3	3	4	3	3	5	3	5	3	5
R10	2	4	3	5	4	3	5	4	5	5	4	3	5
R11	5	5	3	4	5	4	4	5	3	3	3	4	3
R12	3	5	3	5	4	4	1	5	5	4	4	4	3
R13	3	3	5	3	3	3	2	4	3	3	3	3	4
R14	1	3	5	4	4	4	4	3	4	4	5	5	3
R15	1	5	5	4	4	3	3	3	5	5	5	4	5
R16	2	3	5	5	4	5	5	5	5	5	5	5	3
R17	3	4	4	3	4	3	3	4	3	4	4	5	4
R18	1	3	4	5	3	3	2	4	4	4	4	5	3
R19	4	4	5	3	4	3	2	5	4	4	5	5	4
R20	3	4	4	4	3	3	2	4	3	3	4	4	3
R21	4	4	5	5	4	4	1	3	3	4	5	3	4
R22	5	4	5	3	4	4	3	3	3	3	3	5	5
R23	2	1	5	3	5	5	2	3	4	5	4	5	3
R24	5	3	4	4	3	3	2	3	5	4	4	4	5
R25	2	5	3	3	4	3	4	3	5	3	4	5	4
R26	3	3	4	3	3	5	1	4	4	5	3	3	3
R27	3	1	5	5	5	3	2	4	5	4	3	3	4
R28	3	5	4	5	4	4	3	4	4	5	4	5	4
R29	3	4	4	3	4	3	3	5	3	3	3	4	4
R30	3	1	5	5	5	3	2	4	5	4	3	3	4

5. Results and Discussion

In skill and knowledge of maintenance labor criteria, based on data gained from the questionnaire, most of the respondents (43%) believe that a labor with 3 – 5 years of experience is enough to execute preventive maintenance on steel plants, shown on Figure 1. Inexperienced workers will lead to inefficient work, while over-experienced workers will lead to higher labor cost. In reality, the labor in our steel industry sample has spread experience, from 0 to more than 10 years, as seen in Figure 2.

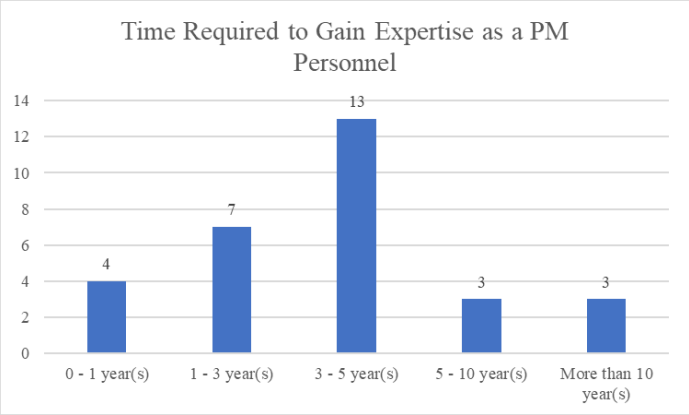

Figure 1. Time Required to Gain Expertise as a PM Personnel

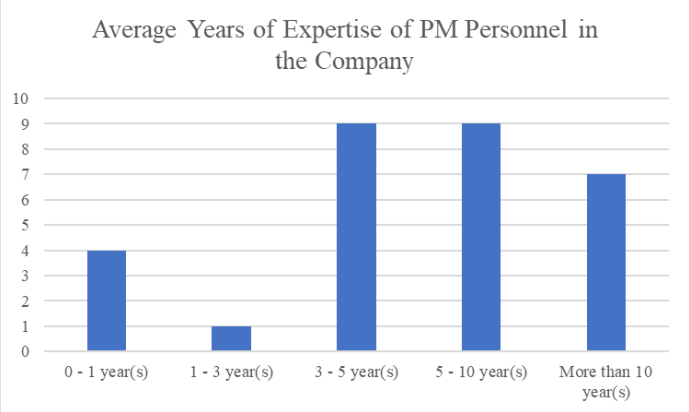

Figure 2. Average Years of Expertise of PM Personnel in the Company

While Figure 3 shows that formal academic degree matters to 20 out of 30 respondents, yet experience is still required to make PM Quality stand out for PM Personnel (Figure 4).

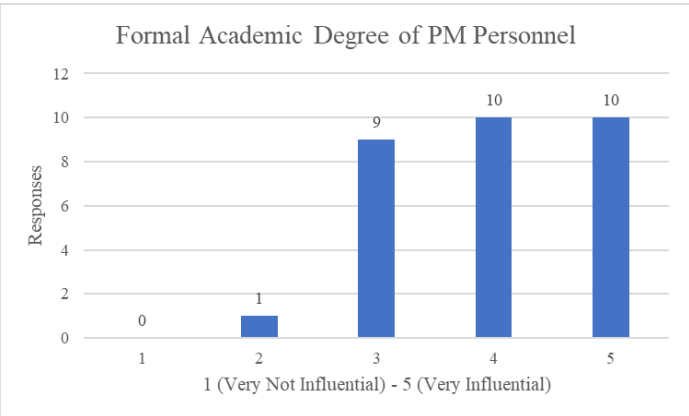

Figure 3. Formal Academic Degree of PM Personnel

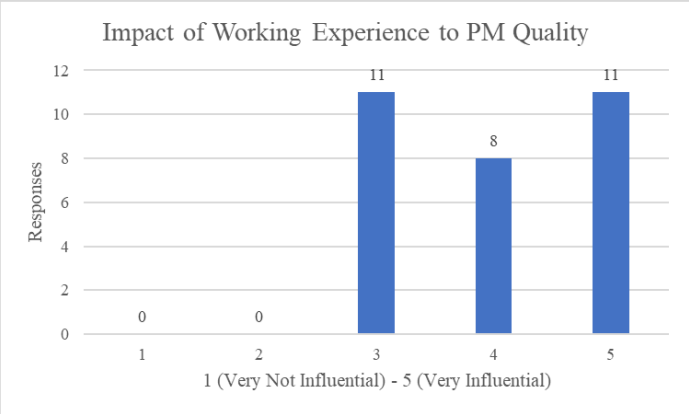

Figure 4. Impact of Working Experience to PM Quality

Even though most of the PM Personnel believe the importance of storage to keep spare parts (Figure 5), unfortunately the majority of PM Personnel find it the availability of consumable and spare parts are only sufficient.

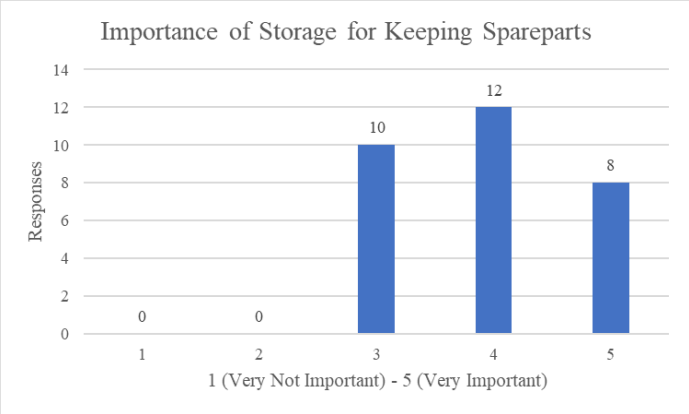

Figure 5. Importance of Storage for Keeping Spare Parts

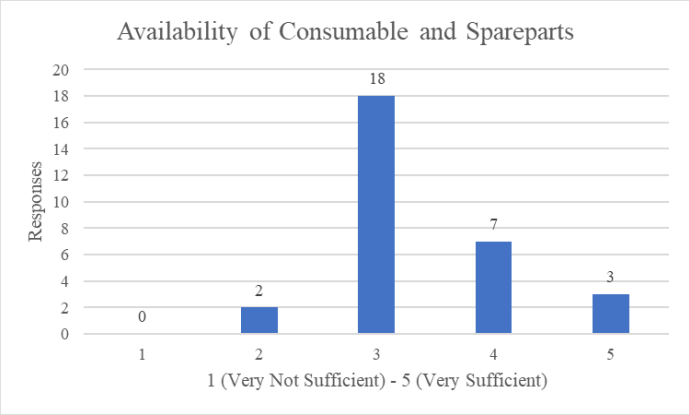

Figure 6. Availability of Consumable and Spare Parts

Figure 7 shows the importance of scheduling between Manufacturer recommendation and PM personnel. Most respondents lean toward manufacturer recommendation as the basis of the PM scheduling interval. However, all

respondents believe that both manufacturer and personnel experience are equally important, as shown in Figure 8 and Figure 9.

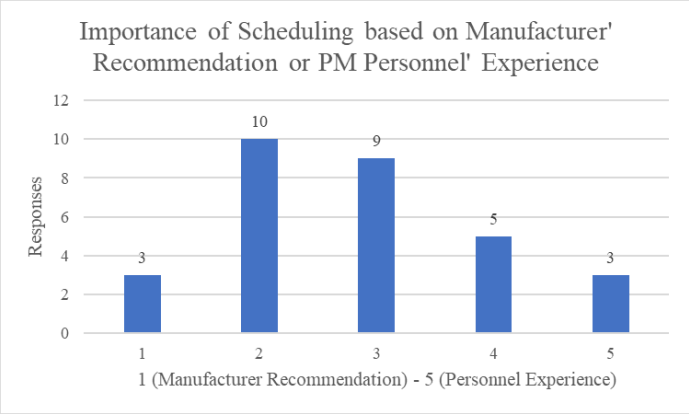

Figure 7. Importance of Scheduling based on Manufacturer' Recommendation or PM Personnel' Experience

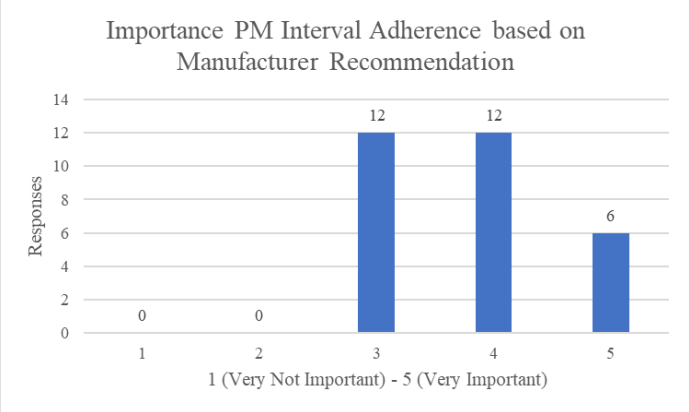

Figure 8. Importance PM Interval Adherence based on Manufacturer Recommendation

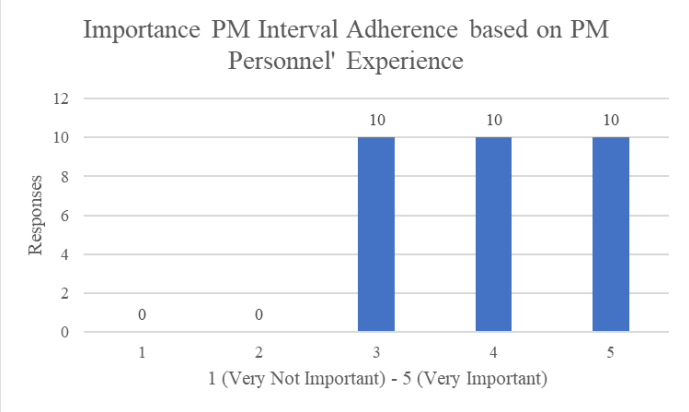

Figure 9. Importance PM Interval Adherence based on PM Personnel' Experience

Figure 10 shows that influence of PM Activities proven to be effective in reducing downtime according to PM Personnel. Supported by sufficiency of supporting tools (Figure 11).

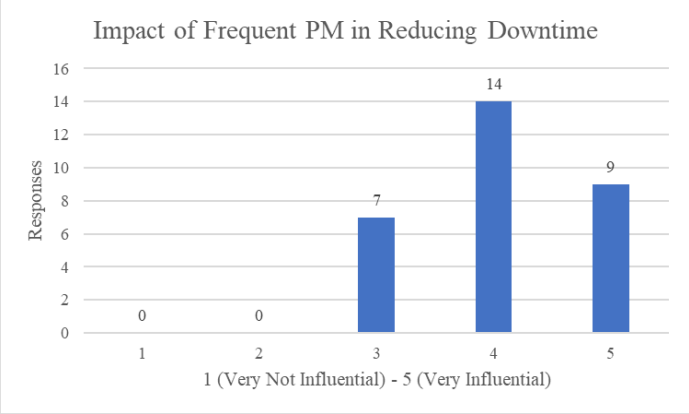

Figure 10. Impact of Frequent PM in Reducing Downtime

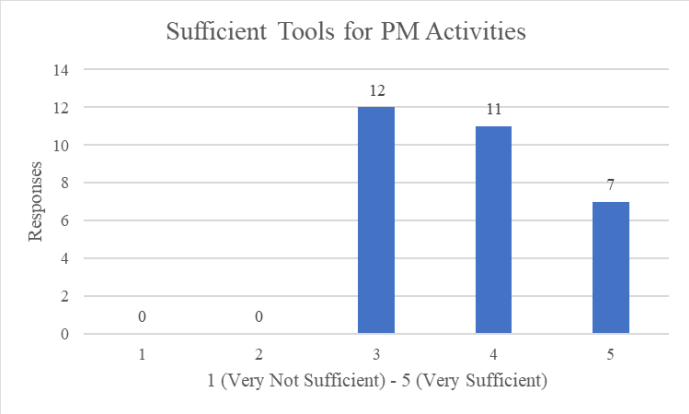

Figure 11. Sufficient Tools for PM Activities

As shown in Figure 12, the data utilization for PM activities seems to be on a good trend with 21 out of 30 respondents utilized and frequently utilized data to enhance their PM quality. Meanwhile 9 respondents said moderately utilized the data.

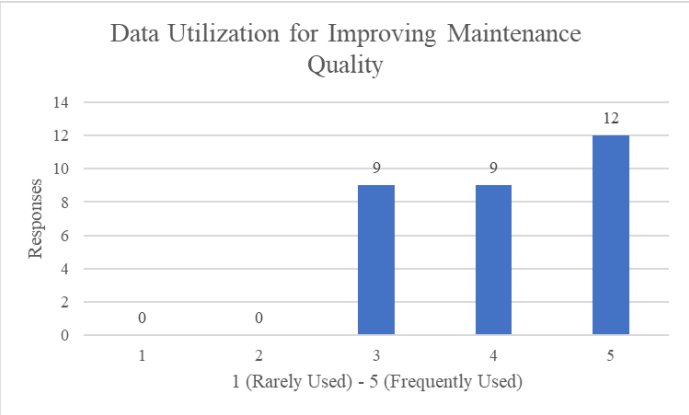

Figure 12. Data Utilization for Improving Maintenance Quality

In terms of financial aspect, perception of sufficiency of the budget allocated for PM activities seems to be different as shown at Figure 13. This is the result of the difference in section and production line where each PM Personnel is assigned.

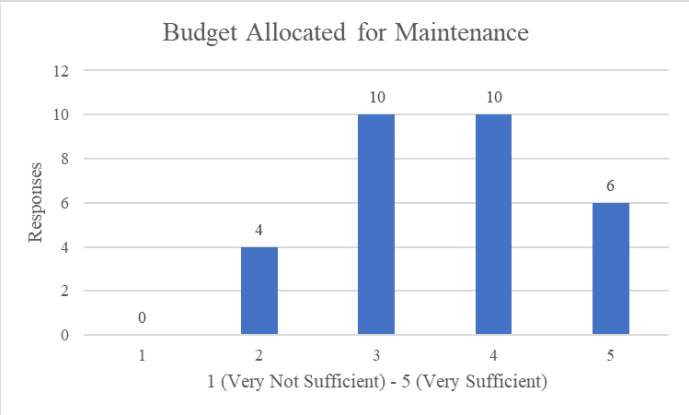

Figure 13. Budget Allocated for Maintenance

6. Conclusion

The purpose of this research is to analyze maintenance characteristics at a steel manufacturer company that has multiple production lines. 13 questions that developed based on the literature review of the preventive maintenance characteristics, namely skill and knowledge of maintenance personnel, spare parts and material, planned maintenance interval, failure and maintenance downtime, maintenance equipment and technique, acquisition of maintenance data, and financial aspect.

In terms of skill and knowledge of the maintenance personnel, most of the respondents believe that formal education and working experiences are influential to preventive maintenance quality, and a labor with 3 – 5 years of experience is enough to execute preventive maintenance on steel plants. In terms of spare parts and materials, it's important to have spare parts and material storage in steel manufacturing companies. This has something to do with the allocated budget to make sure the supporting facilities and tools are sufficient for PM Activities. With the emergence of industry 4.0, most PM Personnel believe that data utilization is influential for improving PM quality. Most of the respondents relied on the manufacturer's recommendations as the basis for the PM planning interval, but believe that both manufacturer recommendation and personnel experience are equally important.

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Biographies

Fauzia Ashwin Hadits is a graduate student in the Industrial Engineering Department of the Universitas Indonesia. She earned a bachelor's degree of Industrial Engineering from Universitas Trisakti.

Giri Aji Anggoro is a graduate student in the Industrial Engineering Department of the Universitas Indonesia. He earned a bachelor's degree of Mechanical Engineering from Universitas Katolik Indonesia Atma Jaya Jakarta.

Hafizh Rifqi is a graduate student in the Industrial Engineering Department, Faculty of Engineering, Universitas Indonesia with a major focus on Industrial Management. He completed his bachelor's degree from Electrical Engineering, Faculty of Engineering, Universitas Gadjah Mada in 2015.