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Research Article

Identifying the Sources of Work-Order Back-logs in a Petrochemical Production Process

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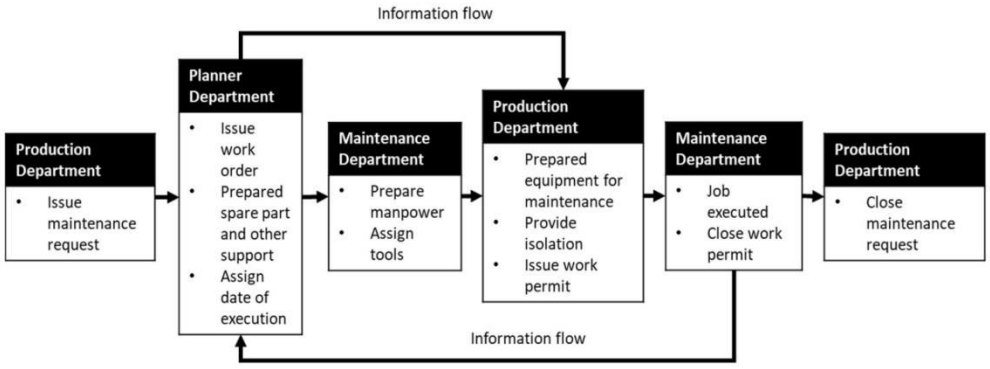
Abstract: As the main goal of the efficiency program, any maintenance department management has to analyze its activities to strive for an excellent performance. One area of improvement is to maintain maintenance work order management. The point of the activity is to reduce the work order backlog. Managing a significant number of backlogged work orders and the resources required to reduce the work order backlog is critical to having a high-performance maintenance organization. This research is focused on finding the root causes of increasing the work-order backlog in a petrochemical company, leading to the low maintenance performance in the company. A fishbone diagram is used to analyze the root cause of delayed maintenance activity and each aspect of cause rendered into the questionnaire to capture the occurrence, severity, and detection to gain a total score. The finding shown that backlogs do not interfere with the production process so that the product can meet the needs of consumers are 10% of the total work orders that are released each year. The analysis obtained shows that backlog work orders that occur at Petrochemical Company account for 16% of the total Work Orders that are released in March 2019. Preventive and predictive maintenance was applied to improve the equipment reliability in Petrochemical Company and reduce up to 6 % of the backlog in April 2020. the preparation of a maintenance information system with a Computerized Maintenance Management System (CMMS) so that information about machine failure data can be used as a reference to analyze machine conditions and become a reference for making policies.

Keywords: Work Order Backlog, Fishbone Analysis, Maintenance Performance, Work Order Management.

1. Introduction

It is widely known that maintenance has a high impact on business performance, such as productivity and profitability (**Alsyouf, 2007**). Maintenance is crucial for companies in processes and chemical industries such as paper mills, petrochemical, and refineries. Often, they are less intensive in the labor force but more intensive in technology, utilizing expensive and fully automated production lines. In those companies, the importance of maintenance function in the organization is critical due to its role in ensuring operation efficiency, quality, and effectiveness (**Alsyouf, 2009**). In the organization, the maintenance department often needs to work closely with production dan planner departments to achieve excellence in productivity. Figure 1schematically shows the inter-relationships between departments.

Figure 1.The flow of work order information between departments in the organization.



A workorder is a task or a job assigned to a function or department. For the maintenance department, the work-orders are often involving maintenance, repairs, or operations. The production department often initiates the work orders, and then the planner department determines the execution date and the required resources. Finally, the planned execution is shared with the maintenance and production departments.

Upon receiving the information, the maintenance department should prepare the required workforce and necessary tools. The production department should prepare a work permit and equipment and isolate the affected areas for maintenance. Upon completion, the maintenance department should return the work permit, and the production department should close the requested ticket. However, in practice, the flow of maintenance work-order does not always go smoothly. Sometimes, the ordered work could not be finished during the assigned execution date for various reasons. The situation produces a work-order backlog, which further needs to be re-planned and re-executed following similar steps.

The work order is the main instrument used in monitoring, planning, and reporting all maintenance activities (**Manzini et al., 2010**). Work order backlog is an order that has to be rescheduled due to problems or delays in its implementation.Some internal problems in the company include labor shortages, unavailability of spare parts, changing the priority of the work orders, inaccurate planning, and lack of communication. When there is no interruption in the execution flow of the workorder, the backlog workorder would not be raised. The occurrence of the backlog workorder reflects the interruption of the workflow process. Therefore, the number of work-order backlogs is often used as a key performance indicator (KPI) representing the achievement of the maintenance department.

Moreover, many approaches have been explored to improve the performance of the maintenance department, including the popular lean six sigma (LSS) framework (**Hill et al., 2018**). The lean and six sigma approach are widely known for improving business performance. Lean and six sigma are two different approaches but are often used in parallel to improve operational efficiency and to reduce the variation in the output of processes (**Narottam et al., 2019**).

In general, business activities can be categorized into value-added (VA) and non-value-added (NVA) activities (**Mcintyre, 2009**). The lean method comprises the implementation tools aiming to reduce NVA or `waste' (**Bortolotti et al., 2015**). The goal of utilizing lean is to meet the customer demand as efficiently as possible by having minimum NVA activities such as machine downtime, inventories, scrap, rework, and other hidden waste (**Trehan et al., 2019**).

The six sigma method involves many statistical and non-statistical methodologies for systematic improvement to achieve a desired level of quality in process or product outcomes (**Antony, 2011**). The notable difference between lean and six sigma is that lean is implemented with the philosophy of incremental improvement that might arise from the organization's bottom. In contrast, six sigma is a breakthrough improvement that is commonly initiated by top-level management. Despite its differences, the combined application of both approaches has been reported to successfully improve operational excellence (**Trehan et al., 2019**).

In recent publications, we witness the rising interest inthe implementation of the lean six sigma approach as an improvement project in many sectors (**Singh and Rathi, 2019**). In the service industry, **Adhyapak et al. (2019)** review the use of define, measure, analyze, improve, and control (DMAIC) six sigma methodology in a selected transportation cab service industry to improve customer satisfaction levels. **Wang et al. (2012)**describe how lean six sigma can be applied to quality management of equipment maintenance. LSS is applied to reduce inefficiency in equipment maintenance. **Hill (2018)**discusses the implementation of a lean six sigma framework to enhance operational performance in a Maintenance Repair and Overhaul (MRO) facility. Furthermore, with the increasing concern on sustainability, the sustainable lean six sigma approach is getting more recognition, as reviewed by**Parmar et al. (2019)**.

Despite the fact that numerous research has been investigated the benefit of implementing the LSS framework, this study is inspired by a particular tool in the LSS framework, which is the fishbone diagram, also known as the cause and effect diagram or Ishikawa diagram. The Fishbone diagram is often considered one of the main tools used in LSS implementation(**Lee and Chang, 2012**). Therefore, it is interesting to see how these tools can be implemented in this study. Thus it is essential to address this as the contribution of our studies, to the best of our knowledge, a study that observes explicitly how the production process in the petrochemical industry, especially the analysis on backlog work order improvement using fishbone diagram in the petrochemical industry is needed to be further explored. This study uses the fishbone diagram to analyze various decisions related to the work order backlog that potentially improves the production process of the petrochemical industry. Most importantly, the analysis on the cause of a high number of work-order backlog is necessary. The analysis is helpful in suggesting an action plan to reduce the work order backlog.

The remainder of this paper is organized as follows. In Section 2, we briefly describe the research method. In Section 3, we present the research findings statistically and discuss their implications. Finally, we conclude the research with Section 4, which summarizes the significant findings.

2. Research Methods

The study is conducted in a petrochemical company, established in 1974 and operates for more than 46. The company is committed to continuous improvement and lean processes in every aspect of its activities to stay competitive in the market. The company manufactures ethylene with a total capacity of 800 kilotons per annum consisting of 700-kiloton polyethylene and 70-kiloton sulfur. Industries Qatar (80%) and Total Petrochemicals of France (20%) are the company's principal shareholders.

The company faces a serious challenge with the sharp fall of 40% of the oil price from July 2015 to July 2020. The ethylene price falls by 15% to $834 per metric ton. The propylene price falls by 10% to $786 per metric ton. For this reason, the company executed an efficiency program to identify, analyze, evaluate, and optimize all business activities, including those in the maintenance department, to achieve excellent performance.An area of improvement is the maintenance work-order management to achieve proper maintenance goals according to the schedule provided and to avoid unplanned shutdowns on tools and machines. In particular, the goal is to reduce the work-order backlogs to 10% in a year and maintain the production time to 90% in a year. This study aims to find the leading causes of the work-order backlogs. A fishbone diagram is used to identify the causes where they are categorized into aspects related to material, method, machines, measurements, manpower, and environment (**Ershadi et al., 2018**). In this study, a work-order backlog is defined as the failure to execute a workorder.

One of the failure analysis techniques that have been applied in various fields is Failure Mode and Effect Analysis (FMEA) (**Liu et al., 2019**). FMEA is a systematic method to identify and prevent problems (**Stamatis et al., 2003**). FMEA emphasizes a hardware-oriented and bottom-up approach. FMEA aims to examine processes and products to determine potential failures and their consequences. In the current FMEA approach, we question end-users about their judgment on the level of severity, occurrence, and prevalence (detection) of problems. The FMEA method presents the risk rating by the value of the Risk Priority Number (RPN). The RPN value is a multiplication of three indicators, namely, the severity (S), the occurrence (O), and the detection (D).

$$\text{RPN} = S \times O \times D.$$

The higher the RPN value is associated with, the higher priority.

In this research, data are collected from two categories: primary and secondary. The primary data are collected by questionnaires provided to managers, engineers, and staff from the maintenance, production, and planner departments. The instrument is provided in Table 1. Besides, the back-order data are directly collected by the SAP system. Figure 2 describes the procedure to collect the back-order data from the system. In total, 6488 back-order works are collected from 40550 work orders.

Figure 2. The process of selecting work-order backlogs from the system.

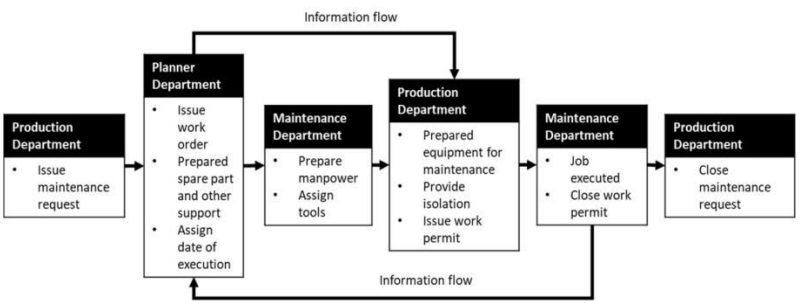


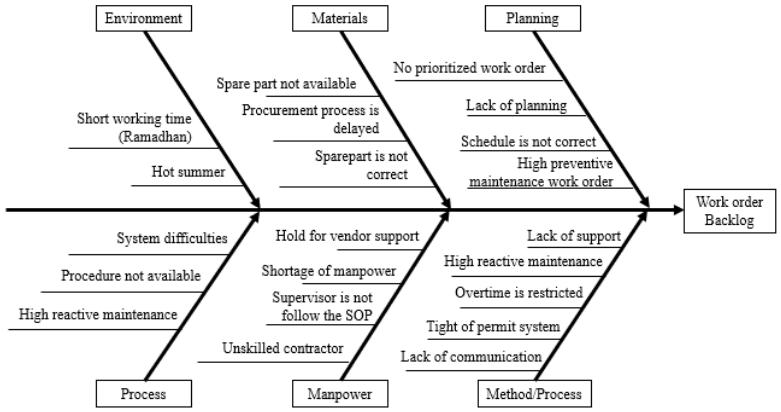
Table 1. The questionnaires

No.	Question	Target	Relation with research Scope
1	When you have rest during your seven days' work cycle, are you still tired, even after waking up from sleep?	To find out maintenance activities either firsthand or prior experience	To ensure the relevance of the topics to be discussed
2	Overall, how the work order backlog is currently available on SSKP Petrochemical Company	To understand the actual conditions that occur regarding work order back-logs	To identify the real issue of the root cause of the work order backlog
3	In your opinion how to handle mainte-nance activities in managing work or-ders released by the company. What do you think about the procedure and man-agement system is sufficient or not sufficient?	To understand howeffective theprocedures andmanagement theyhave	To generally identify management used in handling back-logs
4	In your opinion how important is it to have a low number of work order backlogs? how is the connection with the production target?	To find out the positive impact of the low work order backlog and its effect on the performance department	To get input and suggestions to reduce the number of backlogs that occur
5	What do you think are the main problems that have caused an increase in a backlog work order?	To find out what is the main cause of the high work order backlog	To identify and mitigate problems and as a way to find the main causes of backlog problems
6	Is there a direct factor in the high work order backlog that occurs, whether in terms of personal (human factor)?	To find out what is the main cause of the increasing number of work order back-logs &	To identify and mitigate the main causes of backlog problems
7	How do you manage your work order backlog effectively so you can avoid increasing work order backlogs?	To understand the efforts of organizations and or individuals in solving problems	To find out and analyze how respondents' ideas in handling problems
8	In your opinion how can we increase the target completion of work orders that have been released? how to prioritize work	To know the planning process and priorities to identify the solution that will be taken	To get a realistic solution in reducing the high backlog
9	What do you think is the critical success factor for achieving an accurate level of work order completion?	To find out important factors that apply in the company to reduce the level of work order backlog that occurs	To identify critical sections in the field of knowledge and experience

3. Results and Discussion

The investigation to track down the problems related to the work-order backlog is performed methodologically following the fishbone diagram depicted in Fig. 3. The investigation covers six areas:workforce, method/process, process, environment, materials, and planning. The figure presents the detailed aspects of each area. For instance, within planning, we investigate the aspects of work order, work planning, scheduling, and preventive maintenance.

Figure 3. Fishbone diagram to identify the causes of the work-order-backlog problem.



For each aspect, data are collected from respondents in various levels and areas of employment, including maintenance field support, service manager, senior mechanical planner, rotating equipment and vibration analysis head division, static equipment head division, electrical head division, electrical engineer, instrument engineer, control system head division, rotating engineer and rotating supervisor in the company. Each respondent is presented with the form depicted in Figure 4 and is requested to fill the columns labeled with severity, occurrence, and detection with values from one to four. The last column, labeled with the total Risk Priority Number (RPN), is filled a value due to the multiplication of severity, occurrence, and detection.

Figure 4. The questionnaire was presented to each respondent.

PENILAIAN AKAR MASALAH BACK LOG WORK ORDER

Data Responden:

Nama : Mr. Adham Elbardawi

Jabatan : FIELD SERVICE SUPPORT MAINTENANCE MANAGER

Pengalaman kerja di SSD LNG Co. : 20 tahun.

No.	Kategori WOB	Deskripsi WOB	Penyebab Masalah	Skala			RPN
				Severity	Occurrence	Detection	S x O x D
1.	Tenaga Kerja	*Work order back log yang disebabkan oleh Tenaga Kerja*	a. Kurangnya jumlah Tenaga kerja	3	3	4	36
			b. Kurang terampilnya tenaga kerja kontraktor	2	2	2	8
			c. Rendahnya pengawasan	1	2	2	4
			d. Kurangnya dukungan pihak Vendor	2	2	1	4
2.	Perencanaan	*Work order Back log yang disebabkan oleh factor Perencanaan*	a. Tidak adanya prioritasi Work Order	3	2	2	12
			b. Buruknya perencanaan	2	4	1	8
			c. Tidak tepatnya penjadwalan	3	2	2	12
			d. Perintah dalam WO tidak jelas	2	1	3	6
3.	Method/Process	*Tingginya Work Order yang disebabkan oleh factor Method/Proses*	a. Buruknya komunikasi	4	2	2	16
			b. Sistem permit yang berbelit	2	2	3	12
			c. Pengurangan jumlah kerja lembur	3	2	3	18
			d. Tingginya Pekerjaan perbaikan	4	4	1	8
4	Material	*Tingginya Work order backlog yang disebabkan oleh Material*	a. Suku cadang tidak tersedia	4	3	2	24
			b. Proses pengadaan barang terlambat	2	3	2	12
			c. Suku cadang tidak sesuai	3	2	3	18
5.	Lingkungan	*Tingginya Work order Back log yang dipengaruhi oleh factor Lingkungan*	a. Pendeknya jam kerja di bulan ramdhan	2	3	4	24
			b. Faktor cuaca pada saat musim panas	1	4	3	12
6.	Sistem	*Tingginya Work Order Back log karena factor Sistem*	a. Tidak tersedianya procedure	1	2	2	4
			b. Tingginya Pekerjaan perbaikan	2	3	2	12
			c. Sulitnya procedure kerja	1	3	3	9

Prior discussing further work-order backlog, we should introduce some types of work orders. The standing work order is a work order that is released permanently or routinely in the system either monthly, or annually. This work order is usually for routine activities generated automatically in the system, such as street lights and elevator work. The draft work order is in the draft condition and is waiting to be scheduled, or the relevant planner has not released the work order. This work order may not be included in the backlog because it is still not released and assigned to the execution team. The canceled works order is those released in the system but is canceled for some reason by the planner. This type of work order needs to be removed from the backlog. The planning work order is those made by the planner for some internal activities such as planning the recruitment of new contractor staff, making work orders for new contracts or services.

This work order cannot be categorized as a work order backlog because it directly affects production activities. The planner team also makes the outside processing work order to set contractor working hours or servicing costs not related to production equipment. Therefore, this type of work order needs to be removed from the work order backlog list. The inspection work order is made by the inspection team activities for several types of equipment, such as the vibration survey on rotating equipment, checking the temperature level, noise level, and corrosive level of the equipment. This type of activity is entirely under the integrity department, so it does not have direct operations to the operations.From the distributed questionnaires, we have identified several significant issues affecting the work order backlogs. Those significant issues are discussed at a great length in the following. The first major issue is related to the lack of a workforce. The simple thing is the relationship between the activities of a job with the number of workers. A sufficient number of workers will produce proportional productivity. The more workforce they have, the faster the work can be completed to prevent backlogs and vice versa. The lack of a workforce will cause the maintenance department to have difficulty completing work orders according to the specified schedule, causing the machine's productivity or equipment to be hampered. The reduced productivity of the tool will impact the income of the production. In some instances, the production cannot meet the target, which will ultimately reduce the profit from the company. From several interviews and collected data, the insufficient workforce in the maintenance department is one of the causes of the high work order backlog that would ultimately disrupt production activities. The lack of workforce can be addressed by increasing the number of skilled employees, hiring new employees having relevant skillsets to complete the pending work order backlogs, or utilizing experienced existing employees to complete new or urgent work orders,

The second major issue is the non-availability of spare parts. From the interview and collected data, the significant issues related to the non-availability of the spare part are the following. In managing spare parts, it is necessary to have a sound system and experienced and skillful operators. Besides, the operators should also predict the essential spare parts required for both reactive and preventive maintenance. For spare parts required for preventive maintenance, their availability status should be elevated and upgraded using CMMS software. The required spare parts should also be identified from the previously unplanned breakdown affecting work order activities. The procurement process requires considerable time in evaluating bids from suppliers. The procurement process often requires clarification due to unclear offerings. Finally, the supplier takes a long time to determine a reasonable price.

The procurement process may be improved and reduced delays by an early prediction of the required spare parts for preventive maintenance activities, identifying the tools that often break down and the required spare parts, creating a list of required spare parts by using CMMS software, developing better communication between the procurement and inventory department regarding the required spare parts and existing stock, and simplifying the procurement procedures.

The third major issue is the insufficient skillsets of the contractor workforce. Many petrochemical companies utilize contract workers, particularly for activities related to maintenance. In the present case, the contractor workforce is deployed for maintenance activities related to mechanical static, rotating, equipment rental; valve and mechanical sections and machinist; and electrical and instrument. For the issue, the interview dan data suggest that the issue can be mitigated by improving the quality of the selection process, including the test sets for evaluating the worker skillset level, developing or intensifying training programs involving contract workers, and building better communication between the management of contract workers and company management to build synergistic cooperation following the company needs.

The next major issue is related to work order prioritization. Figure 6 shows the procedure of the work orders, which started from the requestor and ended on the executor. The SAP system manages the work order. A critical issue related to the workflow is the selection of the work priority by the requestor. Three available options are urgent, high, medium, and low. Mistake in selecting a suitable option for each work leads to wasted allocated time

and the disrupted preventive maintenance, disruption and hampering of the critical works, reducion of the satisfaction level in operation, and ineffective schedule and function of the maintenance planner.

The next major issue is related to the lack of planning and communication. Poor communication and planning are related and are often a significant hindrance. Planning and communication are essential to ensure all resources, including workforce, spare parts, and standard and special equipment. Work order backlog caused by:

a. Spare parts are not available, can be done by: (1) Predicting the need for spare parts needed, especially for preventive maintenance, (2) Identifying tool parts for which are often needed in the breakdown section, (3) Ensuring the CMMS program records all spare parts needed, (4) Establish good communication with the procurement of goods and the inventory, (5) Review the procurement procedures with more accessible.

b. The lack of skilled Contractors / Helper can be done by: (1) Improving the quality of the recruitment process of contract workers more selectively, (2) Creating training programs to improve the skills of contract workers, (3) Building good communication between management and contract labor providers about the required criteria

c. Supervisor Not Completing Work Orders can be done by (1) Making periodic reports to supervisors every week regarding the number of backlog work orders as a control, (2) Making it as one of the ongoing targets of each supervisor, and becoming one of the monthly KPIs, (3) Reminding all supervisor disciplines to monitor the status of the Work Order that has been given.

d. The absence of Priority Work orders can be done by: (1) Ensuring the operation to use priority matrix in making Notifications in SAP, (2) Making training programs in the use of priority matrix and conducting periodic inspections, (3) Giving priority in each work order in a release.

e. Poor communication and planning can be done by: (1) Ensuring data that is updated for the availability of labor in SAP, (2) Improving communication lines with the execution party regarding the schedule and activities to be carried out, (3) Ensuring reports and scheduling quality, (4) Make a list of lessons learned from problems regarding work order backlogs that occur.

4.Conclusion

Work orders backlogs are several work orders that have been scheduled. However, problems or delays in implementation may arise due to internal company problems such as shortage of labor, spare parts not being available to complete the work, or the lack of contractor staff skills. , the implementation supervisor did not complete the work in the system. There is no prioritized work order, lack of communication, lack of planning.

Preventive and predictive maintenance must be improved to maintain the reliability of Petrochemical Company equipment and prepare a maintenance information system with Computerized Maintenance Management System (CMMS). Information about machine failure data can be used as a reference to analyze machine conditions and become a reference for making policies.

For further research, we should seek solutions to minimize the work order backlog based on problem root causes analysis, existing data, literature review, respondents' feedback during the interview, brainstorming with the Senior Planner and Scheduler. Several recommendations are proposed as an alternative of the solutions for implementation focus to improve current management practices.

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