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Enhancing Efficiency in Aircraft Maintenance: A Lean Six Sigma Approach to Address Time Wastage in Installation Operation

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ABSTRACT

The global Maintenance, Repair, and Overhaul (MRO) industry are experiencing significant growth, particularly in wide body and narrow body aircraft segments. However, operational efficiency challenges persist, as demonstrated by excessive time wastage during the installation process within an Indonesian MRO company. This paper employs the Lean Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) framework to identify and address the root causes of this time wastage. Through Value Stream Mapping, Why-Why Analysis, and the implementation of innovative solutions such as a dedicated screw box and QR code stickers for material management, this research aims to streamline the installation process, reduce waste, and improve overall efficiency. The anticipated outcomes include a remarkable 40-minute reduction in material search time, an 80% increase in Process Cycle Efficiency (PCE), and a substantial and lasting improvement in value-added job task efficiency. This study contributes valuable insights to the aviation maintenance sector's pursuit of operational excellence and customer satisfaction.

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1. INTRODUCTION

In 2022, a disconcerting statistic came to light within one of Indonesia's MRO (Maintenance, Repair, and Overhaul) companies: the Total Deviation between Plan and Actual for 26 projects reached an alarming 2,464.33 hours [Citation Needed]. This data underscores a pressing issue that profoundly impacts operational efficiency. When evaluated within the context of a standard work schedule accounting for 16 man-hours per day, equivalent to two work shifts, the Total Deviation (D-) translates into an astonishing 154 working days. This extended deviation underscores a critical problem necessitating immediate attention.

Through comprehensive interviews with key personnel actively engaged in MRO operations, including engineers and technicians, a significant portion of this deviation was attributed to the time-consuming process of preparation required for installation. While seemingly a minor issue, the repercussions of this inefficiency extend far beyond time wastage, encompassing potential quality assurance lapses and their implications for customer satisfaction.

This research seeks to address this multifaceted challenge through the systematic application of Lean Six Sigma methodologies, specifically the DMAIC (Define, Measure, Analyze, Improve, Control) framework. By combining the power of Lean Six Sigma with DMAIC, we aim to identify, analyze, and rectify the root causes of the protracted deviation between planned and actual project timelines. In doing so, we endeavour to not only streamline the MRO process but also bolster its efficiency, quality, and overall effectiveness.

Several notable examples have demonstrated the transformative potential of Lean Six Sigma methodologies, resulting in substantial reductions in unproductive activities, defect rates, setup times, build times, and lead times, while simultaneously increasing value-added time and customer satisfaction. Krishna et al [1] The implementation of proposed solutions has resulted in drastic reduction of unproductive activities expending 19 min work time. Barot et al [2] After using Six Sigma method, the defect decreased form 15,9% to 6.4%. Roriz et al [3] s result it was achieved an average reduction of 47% in the setup time, corresponding to 10114€ of monthly profit. Thomas et al [4] The key improvements were seen as; Build time reduction of 20.5%, improved on-time-in-full delivery to customer by 26.5%, reduced value-added time by 5% and reduced non-value-added time by 44.5%. Daniyan et al [5] 27.9% reduction in the lead-time, 59.3% increase in the value-added time and 71.9% reduction in the non-value-added time after the implementation of the LSS approach.

Therefore, this paper employs the DMAIC method to address the issue of time wastage within an Indonesian MRO company’s installation operation. This study stands as a testament to the commitment to excellence in the MRO industry, as it strives to bridge the gap between operational aspirations and real-world outcomes, all while ensuring the highest standards of aviation safety and customer satisfaction.

2. LITERATURE REVIEW

2.1. Lean Six Sigma

The Lean approach, rooted in the Toyota Production System (TPS), offers a versatile philosophy that can be applied across various industries. It centers on the elimination of waste, reduction of inventory, and enhancement of throughput, providing a structured framework for problem identification and the proposal of effective solutions [6]. Lean manufacturing, often defined as a prescribed manufacturing method, is geared towards waste reduction, shorter process cycles, increased process flexibility, and improved product quality [7][8]. At its core, Lean manufacturing places a strong emphasis on maximizing customer value while minimizing waste, striving for operational excellence by generating more value using limited resources.

The fundamental tenet of Lean manufacturing revolves around the efficient elimination of waste and the continuous improvement of production processes. It is important to note that the adoption of Lean principles for waste elimination and the enhancement of operational efficiency is steadily gaining traction and recognition within various industries. As organizations seek ways to optimize their processes and deliver higher value to customers, the principles of Lean are becoming increasingly relevant and integral to achieving these goals.

2.2. Why-Why Analysis

Why-Why Analysis, often known as the "5 Whys," is a practical problem-solving technique rooted in the Toyota Production System (TPS) [9]. This approach involves asking "why" repeatedly to uncover the underlying causes of issues, akin to peeling the layers of an onion to reach the core problem. It emphasizes the importance of delving deep into problems rather than simply addressing surface-level symptoms, fostering a thorough understanding of root causes.

Why-Why Analysis finds application across a wide array of scenarios, from manufacturing defects to service-related challenges and personal problem-solving. Its advantages lie in its simplicity, cost- effectiveness, and emphasis on preventing recurring issues through continuous improvement. However, it does have limitations, including subjectivity and the potential to oversimplify complex problems. Nevertheless, when integrated with other problem-solving methodologies, such as Fishbone Diagrams and the DMAIC process from Six Sigma, Why-Why Analysis becomes a valuable tool for organizations aiming to enhance processes, reduce defects, and continually improve their operations.

2.3. Value Stream Mapping

Value Stream Mapping (VSM) is a powerful tool used in Lean and Six Sigma methodologies to visualize and analyze the flow of materials, information, and processes within an organization [10]. It provides a detailed representation of how products or services move from the initial concept to the customer, helping organizations identify inefficiencies and opportunities for improvement. VSM is rooted in the principles of Lean thinking, emphasizing the elimination of waste and the optimization of value-added activities [11].

VSM is widely adopted across industries to enhance operational efficiency and reduce lead times [12]. It enables organizations to identify bottlenecks, excessive inventory, and nonvalue-added steps in their processes. The insights gained from VSM can lead to significant improvements in productivity, cost reduction, and customer satisfaction. While it is a valuable tool, its effectiveness depends on the accuracy of data collection and the commitment of the organization to implement the identified improvements.

2.4. *Fishbone Diagram*

The Fishbone Diagram, also known as the Ishikawa Diagram or Cause-and-Effect Diagram, is a versatile and widely-used tool in problem-solving and root cause analysis. It was first developed by Dr. Kaoru Ishikawa in the 1960s as a visual means to identify and understand the various factors contributing to a specific problem [8]. The diagram takes its name from its shape, resembling the skeleton of a fish, with the problem or effect at the head and "bones" representing categories of potential causes branching off. These categories, typically organized into six major groups (the 6 Ms: Manpower, Machinery, Materials, Methods, Measurement, and Mother Nature), help teams systematically explore and analyze the root causes of a problem.

The Fishbone Diagram's strength lies in its simplicity and effectiveness in facilitating group discussions and problem-solving efforts. By visually mapping out potential causes, it encourages Cross functional collaboration and a holistic understanding of complex issues [13]. The tool is applicable across various industries, including manufacturing, healthcare, and service sectors, and aids in identifying both immediate and underlying causes of problems. While it is an invaluable tool, its successful application depends on the thoroughness of data collection and the expertise of the problem-solving team.

3. RESEARCH METHODOLOGY

This research takes place within the operational context of an Indonesian Maintenance, Repair, and Overhaul (MRO) company, with a specific focus on the installation process. The methodology employed in this study seeks to explore and enhance the installation process's efficiency by identifying and addressing non-value-added activities. The methodology can be summarized into three key phases:

1. Defining Research Scope and Objectives: The initial step involves clearly delineating the research's scope and objectives. By establishing the boundaries of the installation process within the Indonesian MRO company, the research aims to achieve a specific set of goals centered on the recognition and mitigation of non-value-added activities to improve process efficiency.
2. Value Stream Mapping (VSM): Subsequent to the scope definition, Value Stream Mapping (VSM) is employed to visually depict and analyze the entire installation process. VSM serves as a valuable tool to comprehend how materials, information, and activities flow within the organization. It allows for the identification of bottlenecks, waste, and potential areas for improvement. VSM provides a foundation for comprehending the current state of the installation process.
3. Why-Why Analysis and Fishbone Diagram: In the analysis phase, the Why-Why analysis, often referred to as the Five Whys technique, is utilized to delve into the root causes of identified issues or inefficiencies. This method entails iteratively asking "why" to uncover the underlying factors contributing to a problem. Additionally, the Fishbone Diagram, also known as the Ishikawa Diagram, is applied as a visual aid to systematically categorize and examine potential causes.

Through these analytical approaches, this research seeks to pinpoint and scrutinize non-value-added processes within the installation operations. The goal is to provide valuable insights into areas where improvements can be made to enhance operational efficiency within the Indonesian MRO company. By systematically addressing and eliminating waste and inefficiencies, this methodology endeavours to contribute to improved overall operational performance.

4. FINDING AND DISCUSSION

During an interview conducted with an engineer and a technician, it was revealed that there is excessive and unnecessary motion involved in the installation operational process. A review of the company's flowchart for the installation process identified three core processes, with one particular sub- process standing out as consuming an excessive amount of time. Interestingly, this sub-process does not contribute any discernible value to the installation process, yet it remains a necessary component of the overall operational procedure. Consequently, the focus of our observation and analysis will centre on this specific sub-process.

Furthermore, within this identified sub-process, it became evident that there are two processes classified as necessary but non-value-added activities that are also consuming an inordinate amount of time. As such, our proposal seeks to develop new or modified action plans aimed at reducing the time required for these processes while simultaneously eliminating unproductive and wasteful elements.

The forthcoming sections of this academic journal article will concentrate on the elimination of non- value-added activities and a comprehensive analysis to identify the root causes of defects. Ultimately, our aim is to implement lean techniques to enhance operational efficiency and effectiveness

4.1. DMAIC Methodology

4.1.1 Problem definition phase (Define)

The problem definition phase aligns with the primary objective of this research, which aims to address issues within the installation process, pinpoint the underlying causes of waste generation, and enhance the installation procedure by incorporating the Lean Six Sigma methodology. To gain a comprehensive understanding of the installation process, the Value Stream Mapping technique was employed. This approach sheds light on both value-adding and non-value-adding activities, as well as the prerequisites essential for meeting performance benchmarks.

Table 1 provides a summary of installation tasks along with their associated time requirements, critical information essential for calculating process cycle efficiencies. Figure 1 illustrates the VSM representation of the installation process, while Figure 2 delves into the intricate details of the sub-process related to installation preparation. Notably, Figure 2 highlights the presence of two necessary yet non-value-adding activities that consume a substantial portion of time, accounting for 80 out of a total 125-575 lead time.

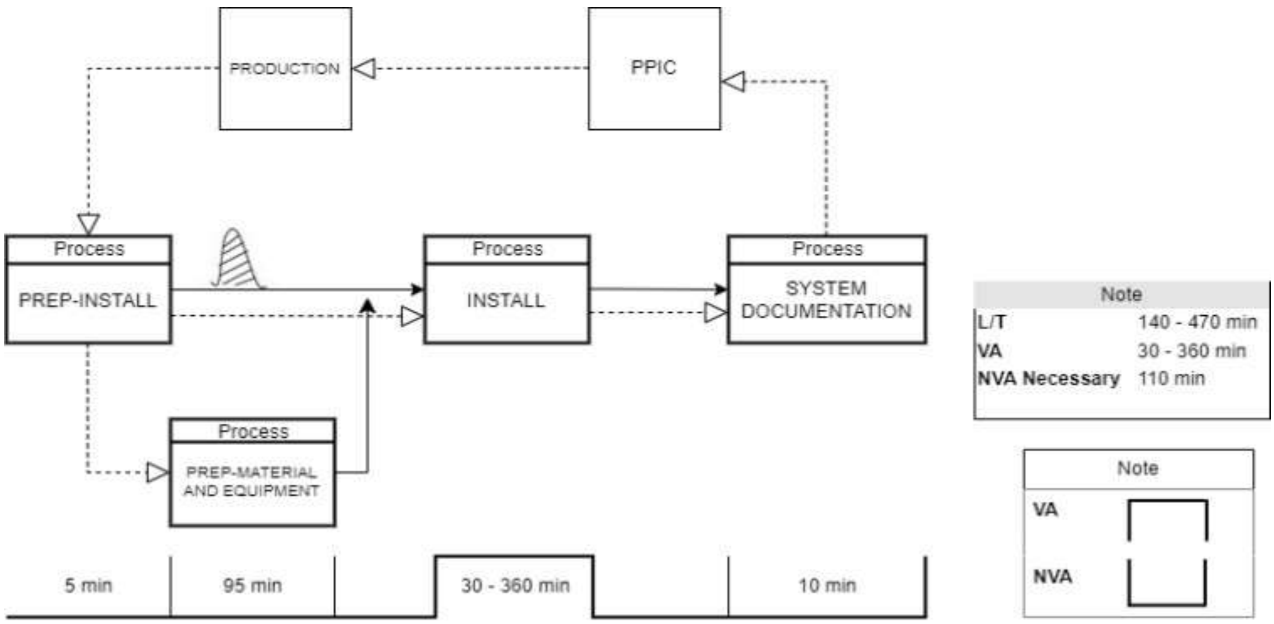

Figure 1. VSM Install Step

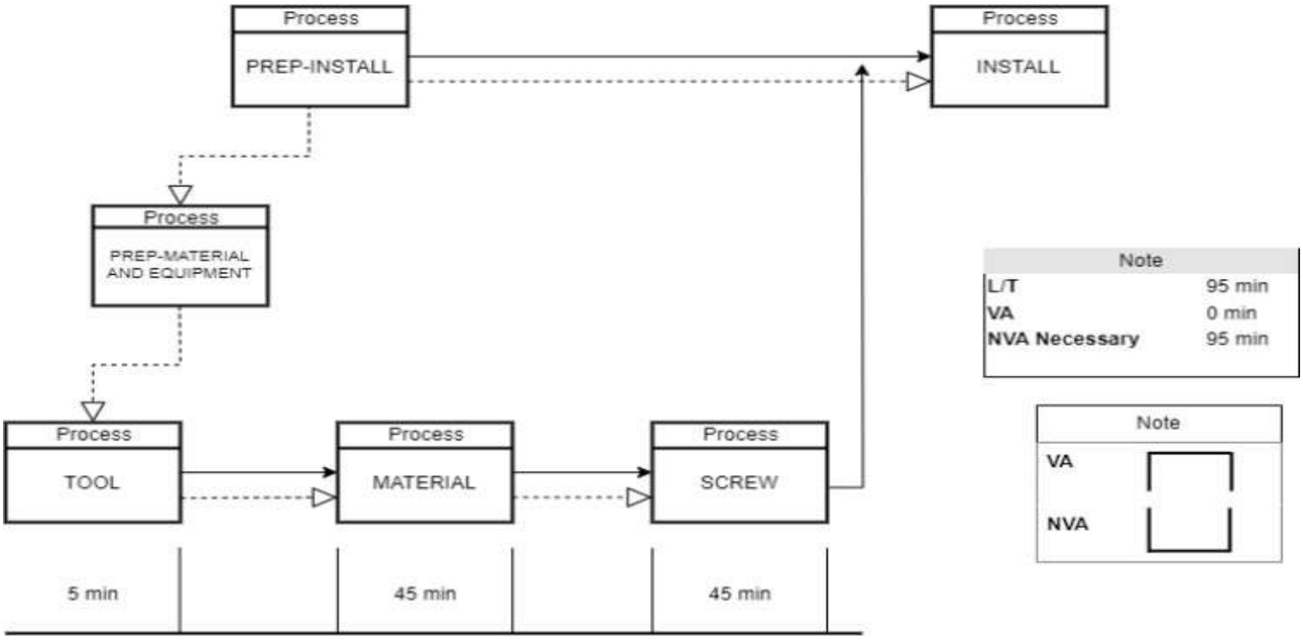

Figure 2. VSM Prep-Install

Table 1. The Installation process of Restore/Replace

OPERATION	TIME (min)
<u>Preparation</u>	
Take tool from tool storage	5
Searching for and retrieving the required materials	45
Searching for and retrieving the required screw	45
Installation	30-360
System Documentation	10
Total	**140-470**

4.1.2 Measurement Phase (Measure)

The incorporation of Lean Six Sigma methodologies is anticipated to yield reductions or eliminations of inefficiencies within non-value-added processes. A scrutiny of the Value Stream Map pertaining to the installation process, particularly the sub-process of installation preparation, has revealed two activities that consume a disproportionate amount of time: the search for materials and screws. Data collected from these observations have been tabulated in Table 2, employing the Process Cycle Efficiency (PCE) equation to illustrate existing operational efficiency [14]. Five distinct scenarios, as presented in Table 2, have been employed to calculate PCE.

The present Process Cycle Efficiency of the installation process is expressed as Eq. 1

$$Present\ Lead\ TIme = Value\ Added\ Time + Non - Value\ Added\ Time$$

$$Process\ Cycle\ Efficiency = \frac{Value\ Added\ Time}{Lead\ Time}\ x\ 100\%$$

Table 2. Process Cycle Efficiency calculate

No	Value Added (min)	Non Value Added (min)	Total Lead Time	Process Cycle Efficiency
1	30	95	140	**24%**
2	112	95	222	**54%**
3	195	95	305	**67%**
4	277	95	387	**74%**
5	360	95	470	**79%**
Total (average)				**60%**

According to the data depicted in Table 2, the estimated average PCE stands at 60%. While the current operational processes demonstrate a degree of adequacy, there remains room for enhancement, underscoring the pursuit of continuous improvement.

4.1.3 Analysis Phase (Analyze)

In this phase, the investigation into the installation process aims to uncover the fundamental causes behind excessive time wastage during the preparation stage. This endeavour involves collaborative efforts, inclusive of discussions and brainstorming sessions among personnel and managers. Potential sources of the problem in the preparation phase are identified using a fishbone diagram and the "why- why" analysis technique.

Through brainstorming sessions involving production managers and personnel, the iterative "five whys" interrogative tool was employed to delve into the underlying root causes and cause-effect relationships contributing to the identified challenges. The purpose of employing the "five whys" technique is to discern the root cause of organizational challenges that likely contribute to the time wastage in the preparation process. A series of questions were posed to understand why the problem occurred and to identify its root cause. The identified challenges and their potential root causes were documented.

From the analyses and brainstorming sessions, it became apparent that the behaviour of certain personnel may be a contributing factor to the challenges. Additionally, other causes were categorized into six primary domains: policies, physical layout, personnel, procedures, processes, and quality control. These categories are represented in a fishbone diagram, as depicted in Figure 3 and Figure 4, and Why-Why Analysis in Figure 5.

It was observed that the inefficient layout of materials significantly contributes to the excessive non- value-added time within the total operational lead time of the installation process. This inefficiency arises because there is no designated storage space for organizing screws, resulting in a mix of good and bad screws in the same location. Consequently, personnel often use the wrong screws, either of varying lengths or similar types. Furthermore, the identification tags for materials are frequently missing or damaged, rendering stored materials unidentifiable.

To address these challenges, several mitigation strategies have been proposed. One solution is to design a dedicated storage area for screws, enabling personnel to organize and categorize them by type and length during the removal process. This way, the problem of searching for screws in subsequent installation processes can be significantly reduced, as screws will already be sorted. Additionally, the use of QR code identification stickers is recommended as an alternative to the current paper-based identification tags. QR code stickers can eliminate issues related to torn or missing tags, providing a more reliable identification method for materials that may not be easily tagged or could have tags detached.

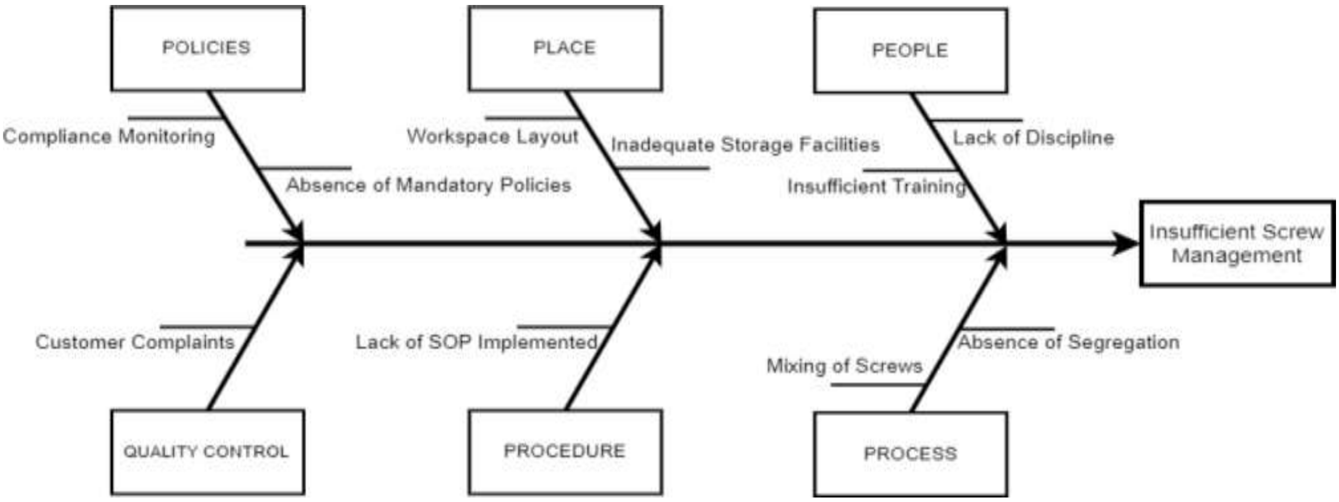

Figure 3. Fishbone Screw

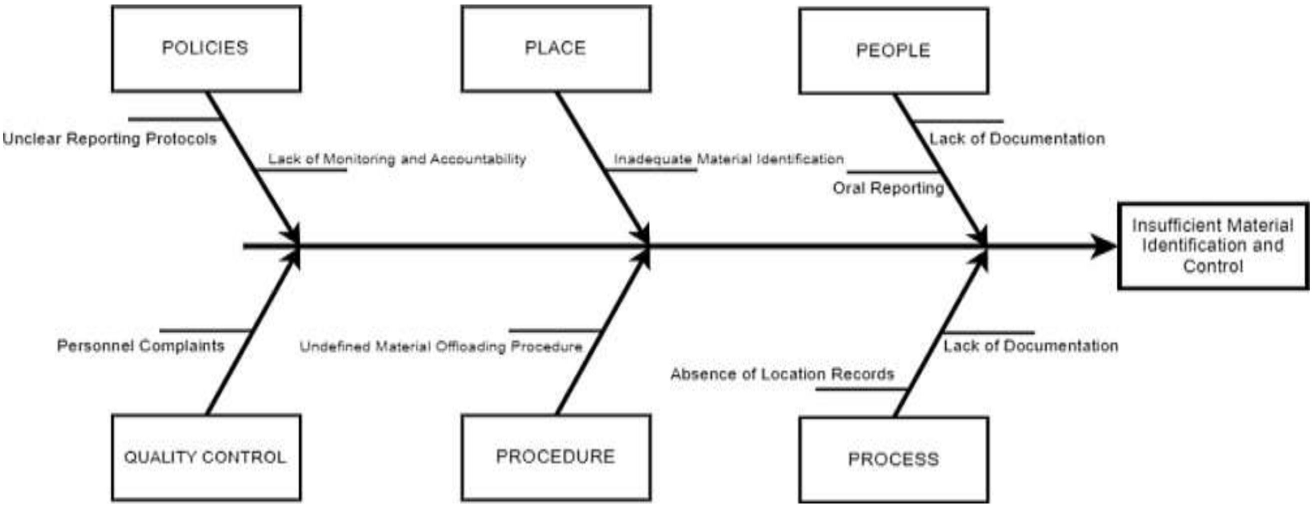

Figure 4. Fishbone Material

Figure 5. Why-why Analyze

4.1.4 Improvement Phase (Improve)

To enhance our installation process, we adopted the Just In Time (JIT) approach, a well-established concept in lean manufacturing (Womack & Jones, 1996). JIT revolves around the principle of optimizing material flow and processes to reduce waste and enhance efficiency. In essence, JIT ensures that personnel spend less time searching for materials and more time on value-added tasks by having the right materials available precisely when needed.

In our context, JIT complements our goal of reducing preparation time during the installation process. This improvement strategy involves the design of a dedicated screw box and the implementation of QR code stickers. These measures align with JIT's core principle of timely material availability and reduction of unnecessary activities.

4.2 Improvement of Screw Management: Screw Box

After engaging in discussions and brainstorming sessions with both personnel and managers to identify an effective storage solution for organizing screws, a practical screw box design emerged. This screw box is designed in the form of a portable case, suitable for use at various project sites. It comprises multiple compartments, including a deep section capable of accommodating a significant quantity of screws. This design is motivated by the observation that job tasks often require two specific types of screws, with occasional additions of two more types. Additionally, these screws vary in length, ranging from short to long. To ensure ease of use and portability, the box is equipped with a secure locking mechanism.

The objective of this solution is to reduce the time spent by personnel searching for specific screws based on type, length, and condition. To achieve this, personnel responsible for the removal process will sort the screws immediately upon removal. Implementation of this screw box, along with standardized work procedures for screw organization, will significantly reduce personnel search times, allowing them to focus more on value-added tasks. Figure 6, Figure 7, and Figure 8 depict the design of the screw box

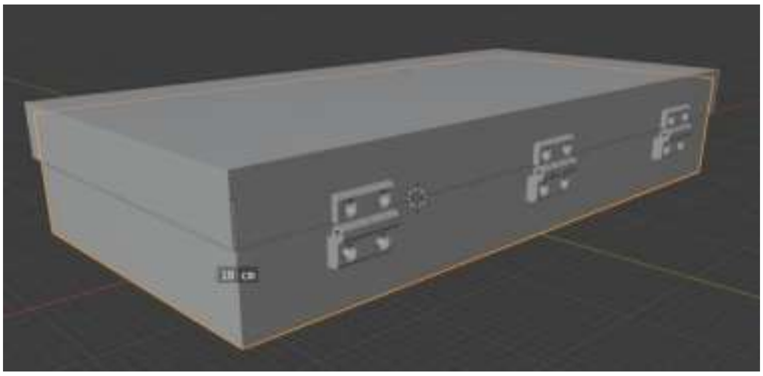

Figure 6. Screw box back view

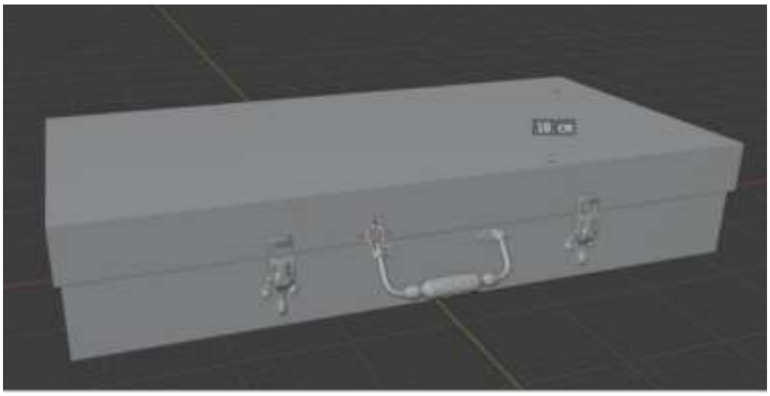

Figure 7. Screw box front view

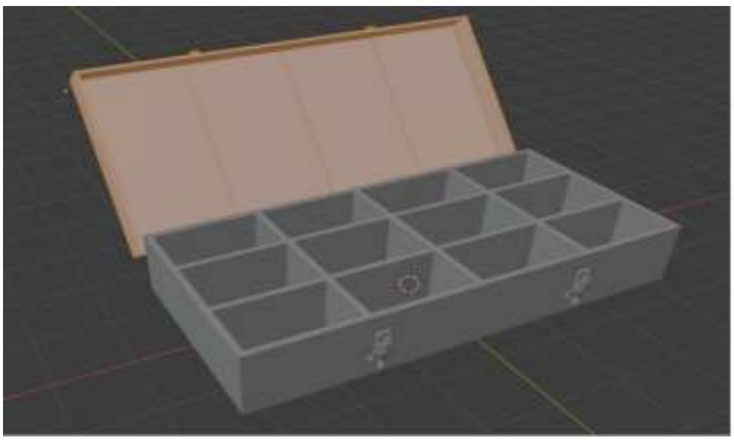

Figure 8. Screw box up view

4.3 Improvement of Material Management: QR Code Sticker

The idea of using QR codes as identity tags for materials was inspired by research conducted in Turkey [15], where QR codes were employed as an identity tag system for healthcare purposes. In that context, QR codes were worn as bracelets, necklaces, or carried as ID cards. These QR codes were linked to a dedicated identity tag website containing detailed information, allowing authorized individuals with smartphones to easily access patient data by scanning the QR code. In the current problem scenario, a similar approach is adopted, with QR codes applied as stickers affixed to materials. Authorized personnel can quickly access material information by scanning the QR code, and for personnel searching for materials, a dedicated app is used to locate materials based on job order numbers, thus reducing search times.

This solution is crucial because, historically, material locations have been communicated orally and not well-documented, especially when identity tags are missing or damaged. The proposed work standardization mandates that personnel responsible for material removal create a QR code sticker with pertinent information (e.g., part number, material owner, removal reason) and affix it to the material. When materials are relocated from their original positions, the responsible personnel must scan the QR code to update the material's new location. Implementation of this solution will lead to significant reductions in wasted time and confusion. Figure 10 and 11 show how the QR Code sticker will be print out for Identity Tag.

Figure 10. QR Code of Test Serviceability Tag

4.4 Expected Outcomes Following Implementation of Proposed Solutions

The anticipated results subsequent to the successful implementation of our proposed solutions are poised to yield substantial enhancements in the efficiency and effectiveness of the installation process. Our primary objective revolves around reducing the significant amount of time currently expended in material search activities. Each solution individually has the potential to curtail this search time from a staggering 45 minutes down to a mere 5 minutes. In essence, this translates to a remarkable 40-minute reduction in search time, heralding a significant boost in operational efficiency.

This projected reduction in search time not only holds the promise of expediting the installation process but also signifies a substantial reduction in the wastage of time resources. This is a fundamental aspect of process improvement, which is integral to our overall objective.

To empirically assess the effectiveness of these solutions, we conducted measurements, as detailed in Table 3, utilizing the Process Cycle Efficiency equation. This measurement exercise was undertaken to gauge the expected outcomes of the proposed improvements.

Table 3. The Expected Efficiency Result after Implementation

No	Value Added (min)	Non-Value Added (min)	Total Lead Time	Process Cycle Efficiency
1	30	15	60	**50%**
2	112	15	142	**79%**
3	195	15	225	**87%**
4	277	15	307	**90%**
5	360	15	390	**92%**
Total (average)				**80%**

Upon evaluating the results following implementation, we observed a noteworthy surge in efficiency. The average efficiency level exhibited a commendable increment, soaring from the initial baseline of 60% to an impressive 80%. This increase in efficiency is indicative of the solutions' efficacy in mitigating time wastage and streamlining the installation process.

Furthermore, when we examined the long-term impacts on job tasks that inherently contribute value to the process, the efficiency levels demonstrated even more remarkable improvements. In such scenarios, efficiency levels reached an impressive 92%, a substantial ascent from the previous efficiency rate of 79%. This marked difference of 13% underscores the substantial and enduring benefits derived from the implementation of our proposed solutions.

5. CONCLUSION

In conclusion, this research aimed to tackle a significant challenge in an Indonesian MRO company: excessive time wastage during the installation process preparation. By employing Lean Six Sigma methodologies, particularly the DMAIC framework, we delved into the root causes of this problem and proposed practical solutions.

Our analysis revealed that the inefficiency stemmed from issues such as disorganized screws and missing material identification tags. To address these, we introduced a dedicated screw box for better screw management and QR code stickers for material identification. These solutions are expected to reduce material search times from 45 minutes to just 5 minutes, resulting in a remarkable 40-minute reduction in search time.

In terms of results, our proposed solutions are promising. We anticipate an increase in overall operational efficiency, with Process Cycle Efficiency rising from 60% to 80%. Moreover, value-added job tasks are expected to become 92% efficient, marking a significant and lasting improvement. These outcomes emphasize the effectiveness of Lean Six Sigma in streamlining processes, reducing waste, and enhancing performance in the aviation maintenance sector

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