Sustainable Well Segment Operational Service Strategy through Standard Work Instruction Design Analysis

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Abstract. The maintenance and productivity of oil and gas wells heavily rely on well service, which is provided by various departments including Laboratory and Maintenance. Although existing work procedures are in place, operational effectiveness and quality are often inadequate, leading to errors, unstructured tasks, downtime, and safety hazards. In order to improve the quality of well service, a set of standardized work procedures based on DMAIC principles is proposed. This paper presents findings from field observations, performance index analysis, and HSE statistics. By implementing redesigned Standard Work Instructions, a reliable mitigation measure is found to be achievable, as evidenced by House of Risk data. The results suggest that a sustainable and effective operational service strategy for well segments can be established through a carefully designed set of Standard Work Instructions.

1 Introduction

The oil and gas industry must meet industrial needs and conduct diverse manufacturing company operations [[1]. One of the essential service activities in this industry is Well Service, which includes activities like drilling, well testing, artificial lift, production software solutions services, and maintenance of wells, and stimulation services [2,3]. Well Service is divided into two components: support and operation. While support is responsible for supporting units, equipment, maintenance and laboratory chemical testing, operation carries out the service activities in the field [4].

As the global oil and gas sector grows, the importance of occupational safety and health for workers, operators, and the environment has become increasingly important especially for companies’ sustainable strategy. Workers who depend on the poor quality of work instructions, will tend to make mistakes, be less efficient at work, resulting in low job satisfaction. It will even cause fatal cases such as death [5]. This however can be managed by developing a sustainable strategy mindset through the quality of information and work methods provided, such as digital technology media representation and easy access to that information as cognitive load was a factor in the decrease of employee performance [6,7]. Moreover, audio-visual is more appealing and effective than text format.

Therefore, digitizing work instructions is a preferred option to paper forms [8]. Standard work instructions have been implemented by the Well Service support segment. However, problems such as downtime, work failures and errors, and HSE performances are still prevalent. This study aims to analyze the issues related to HSE Performance using the Six Sigma method with DMAIC stages to redesign work instruction standards.

2 Literature Review

2.1 Six Sigma DMAIC

There are numerous continuous development and optimization strategies available, including: Plan-Do-Check-Action (PDCA), Kaizen or Lean Manufacturing, and Six Sigma [9]. Six Sigma has emerged as a widely adopted quality management approach in various industries, aiming to reduce process variations and defects. The DMAIC framework, consisting of five distinct phases - Define, Measure, Analyze, Improve, and Control, provides a structured approach for problem-solving and continuous improvement.

The Define phase involves setting clear project goals, identifying key stakeholders, and defining critical-to-quality (CTQ) parameters. The Measure phase focuses on data collection and measurement system analysis to quantify the process performance and identify potential sources of variation[10]. Through the Analyze phase, various statistical tools such as hypothesis testing, regression analysis, and root cause analysis are applied to identify the root causes of defects or inefficiencies. The Improve phase leverages experimental design techniques, process optimization, and innovative solutions to achieve process improvements[11]. Finally, the Control phase establishes control mechanisms to sustain the improvements and prevent process drift over time.

By following the structured approach of DMAIC, organizations can effectively identify and address
process-related challenges, reduce defects, and enhance overall operational performance. The reliance on trusted and reliable references ensures the integrity and accuracy of the information presented in this review, making it a valuable resource for both researchers and practitioners seeking to deepen their understanding of Six Sigma DMAIC.

2.2 House of Risk (HOR)

House of Risk (HOR) is a risk analysis method developed by [12]. The model emphasizes proactive Supply Chain risk management by focusing on preventive actions to reduce the probability of risk agents occurring, which can prevent some of the risk events from happening [13]. Hence, it is crucial to identify both the risk occurrences and the risk agents associated with them. A single risk agent can cause numerous risk occurrences.

In contrast to the Failure Modes and Effects Analysis (FMEA) method, HOR assesses risk differently. FMEA used to assesses risk based on the multiplication of three factors, the severity of the potential failure, the likelihood or probability of the failure occurs, and the ease of identifying the failure also known as Risk Priority Number (RPN) [14]. The higher the RPN, the more attention and resources should be given to addressing that risk. Whereas in HOR, it is divided into two stages: stage 1, the HOR1, determines the priority of preventive actions for risk agents, while in stage 2, HOR2, prioritizes effective actions with reasonable resource commitments [13].

2.3 Health and Safety Environment

Health, Safety, and Environment or also known as HSE, refers to the policies, procedures, and practices that are implemented to ensure the safety and well-being of workers, protect the environment, and prevent accidents and injuries [15]. In industries such as oil and gas, manufacturing, and construction, HSE is of utmost importance due to the potential hazards involved which led to catastrophic accidents, such as oil spills, explosions, and fires if not properly addressed.

Furthermore, with inherent operational risks and potential environmental hazards, oil and gas company demand stringent safety protocols and effective management systems to safeguard human lives, protect the environment, and ensure sustainable operations. Thus, the implementation of robust health and safety measures is of paramount importance to safeguard workers, mitigate potential hazards, and protect the surrounding ecosystems.

There are 3 main domains of HSE, which is Health, Safety, and Environment. Based on [14], these domains are categorized as follows:

- Health- Protection of the human body and mind from illness or hazard due to materials, processes or procedures used in the workplace.
- Safety- Protection of humans against physical hazard. The line between health and safety is defined by these two words and are usually used together to indicate concern for the physical and mental well-being of the individual in the workplace.
- Environment- Regulations covering activities in the workplace that affect or impact the environment, the safety and health of workers and others.

Effective risk assessment is a cornerstone of health and safety management in the oil and gas industry[16]. Rigorous identification, evaluation, and mitigation of potential hazards are essential to prevent incidents and protect personnel[17]. This includes conducting thorough hazard analysis, implementing engineering controls, ensuring proper equipment maintenance, and promoting proactive safety practices. Additionally, the utilization of advanced technologies, such as remote monitoring and real-time data analytics, can enhance risk management capabilities and enable timely intervention.

In the event of an incident, a robust emergency response plan is vital to mitigate the impact and ensure swift and effective actions. Comprehensive emergency preparedness encompasses developing evacuation procedures, establishing communication protocols, conducting regular drills, and providing appropriate training to personnel. Coordinated efforts between the company, relevant authorities, and stakeholders are essential to execute a seamless emergency response and minimize the potential consequences.

The oil and gas industry operates within a framework of stringent regulatory requirements and standards. Compliance with local and international regulations is indispensable to ensure adherence to safety protocols and protect both human health and the environment. This necessitates regular audits, inspections, and monitoring programs to evaluate compliance and address any deviations promptly. Companies must establish robust governance mechanisms and promote a culture of compliance throughout the organization.

3 Methods

The research was carried out at PT. XYZ, a multinational oil and gas services company with its headquarters in Jakarta, Indonesia. Two methods were used to collect data for the study: Field Study, which involved interviews with 30 employees from Maintenance, Laboratory and Field Well Service sub-division department and direct observation. Whilst for literature study, obtained from gathering information from various sources such as maintenance manuals, laboratory manuals, HSE data, and PT XYZ websites. This study focused on optimization of Work Instruction Standards carried out using Six Sigma, a framework designed for process improvement through identifying and eliminating some of the causes that cause defects or failures. The term "six sigma" refers to the unit of standard deviation ($\sigma$), and the higher the sigma, the lower the rate of errors or failures as it was often symbolized by $6\sigma$ [18] The DMAIC framework, consisting of Define, Measure, Analyze, Improve, and
Control stages, was used to improve the process. The stages of DMAIC are summarized in Table 1.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
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<tbody>
<tr>
<td>Define</td>
<td>Customer needs and requirement, set up project, generate process map</td>
</tr>
<tr>
<td>Measure</td>
<td>Select characteristics to improve, define performance requirements, collect data</td>
</tr>
<tr>
<td>Analyze</td>
<td>Establish capabilities, define performance objectives, identify source of variation/error</td>
</tr>
<tr>
<td>Improve</td>
<td>Screen variation sources, identify relationship, recommend solution, set tolerances</td>
</tr>
<tr>
<td>Control</td>
<td>Validate measurement system, confirm solution, build control plan, transition and end project</td>
</tr>
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</table>

Table 1. The stage of DMAIC [19]

At the “Improve” stage, the 2nd phase of House of Risk was also carried out, which then calculate the total value of effectiveness (See equation (2)). Moreover, at the “Measure” stage, risk assessment was implemented by using House of Risk (HOR).

Besides, the risk classification or risk matrix at PT XYZ is presented in Fig. 1 below.

**Fig 1. PT XYZ Risk Matrix**

HSE involves identifying, assessing, and managing risks, as well as implementing safety protocols and training programs to promote a safe and healthy workplace environment. By prioritizing HSE, companies can not only protect their workers and the environment, but also improve productivity, reduce costs, and enhance their reputation. Companies must prioritize HSE as a core value and integrate it into their culture and decision-making processes as the role of regulations and industry standards in ensuring HSE compliance to the degree of implementing proactive and comprehensive measures to manage HSE risks [20].

Finally, HSE was created to protect the well-being and safety of all workers. HSE in most countries is governed by laws and regulations to prevent accidents that cause a loss of value or value. The form of value can either be in the form of workers’ injury or environment pollution. Thus, companies must implement HSE to prevent accidents that can harm workers in the workplace environment.

Fostering a strong safety culture is essential to embed health and safety practices at all levels of the organization. This involves cultivating a proactive mindset, promoting open communication, empowering employees to report potential hazards, and recognizing and rewarding safety achievements. Leadership commitment, employee engagement, and continuous training and education play pivotal roles in establishing and maintaining a sustainable safety culture. In this research focuses on creating new standards operational procedures to minimize risk, implementing preventive measures, establishing effective emergency response plans, ensuring regulatory compliance, and fostering a robust safety culture. Hence, companies can create a safe working environment, protect human lives, and preserve the ecological balance, promoting sustainable operations and minimizing the potential impact of incidents.

### 4 Result and Discussion

Oil and gas industry sees standardization as a tool to streamline operations from design and construction through installation and maintenance, resulting in safer, more predictable, and efficient labor procedures [21]. According to the ISO 90001:2008, work instructions are work mechanism documents that control in depth and explicitly the sequence of an activity that only involves one function as a support for quality processes or work procedures. Procedures often consist of numerous elements that describe the procedures in general. As a result, work instructions include a specific work process as well as a thorough process mechanism. For example, work instructions for tool operation, tool maintenance process mechanisms, and so on. According to [10, 11], DMAIC is an improvement method that uses the define-measure-analyze-improve-control approach to optimize a process, and a risk assessment is performed during the measure stage using the House of Risk (HOR) method. A risk assessment is performed at the measure stage utilizing the HOR (House of Risk) method. House of Risk is a novel approach to risk analysis. The HOR technique is used to determine the probability of a risk agent and the severity of a risk event. Because one risk agent is likely to generate more than one risk event, the risk agent’s potential risk quantity must be aggregated. The Aggregate Risk Potential (ARP) value is then calculated to identify the ranking and priority hazards, which will later define the quickest and most effective mitigation.

#### 4.1 Current Work Instruction Analysis

At PT XYZ, the Well Service division offers module work instructions to its employees. However, the modules can be challenging to understand, which contrasts with the previous labour instructions that included narrative work steps. Additionally, some work steps were not modelled in the earlier instructions. One drawback of the current work instructions is that they
lack information regarding the Personal Protective Equipment (PPE) required for each job. Since each job poses unique work dangers and hazards, it is crucial to have knowledge about the PPE used for specific activities. Moreover, every facility has its own set of standard operating procedures. The current work instruction standards are illustrated in Figure 2 which portrays the Repacking Triplex Pump work instruction module and Figure 3 is a Plug Valve Grease replacement work procedure.

![Fig. 2. Repacking Triplex Pump Work Instruction Module](image)

![Fig. 3. Some of the PT XYZ Current Work Instruction](image)

Based on HSE performance data observation from January 2018 to February 2021, the number of workplace accidents varies from year to year as shown in Figure 3. The year 2019 performed well in comparison to the previous year 2018, however in 2020, even if the number of work accidents decreased, there were catastrophic incidents that were regarded very serious. It is expected that HSE performance would improve in the coming year by decreasing possible dangers, one of which is by introducing standard work instructions that are simple to understand and can be properly implemented by every employee.

4.2 Non-Productive Time (NPT) at Well Service Support Division

The Non-Productive Time (NPT) is an extension of the work plan time that is allocated for a task that has not been completed within the original planned time frame. Any delay in planning or execution results in an increase in the allocation of work time to complete the task. NPT can be caused by a range of factors, including errors, operational work failures, and field faults.

In addition, natural factors such as weather conditions can also result in delays in work execution. To mitigate the impact of NPT, companies often adopt various strategies, such as adding personnel to speed up work, adding work time to each personnel, allocating additional work tools and machines to reduce queues, and rearranging the schedule for using work tools and machines for other jobs. Another strategy is initiating the delivery of spare parts to normally urgent locations. Despite these strategies, NPT can still result in significant financial losses for companies. In the case of Well Service, NPT is found in several work locations for examples Plug Valve Leak in 2020 can cause financial loses around $2500 with 1 hour NPT estimation. Thus, it is imperative for companies to monitor and analyze their NPT rates to determine the root causes of delays and to identify opportunities for improvement.

By doing so, companies can minimize the financial impact of NPT and improve their overall efficiency and productivity.

4.3 Define-Measure-Analyze-Improve-Control

4.3.1 Define Stage: Design and Analysis of Work Instructions with the DMAIC Method

Following the identification of work error problems at PT. XYZ, a fishbone diagram (Figure 4) was constructed to identify the factors causing the problem of work failure and errors. The diagram revealed that there are six major causes of work errors at PT. XYZ, namely techniques, management, machines, employees, materials, and measurement instruments.

Methods were identified as one of the causes of work errors due to the complexity of the work, incomplete Personal Protective Equipment (PPE), errors in work steps, and lack of employee understanding of the methods or ways of working. Personnel-related factors, such as fatigue or exhaustion, lack of skills or abilities, the need for training or job training, and the abilities of the employees themselves were also identified as causes of work errors. To determine the dominant problem, the House of Risks (HOR) method was used to identify the most significant causes and develop a mitigation strategy.
Therefore, by identifying the dominant causes of work errors and implementing mitigation strategies, it is expected that the job performance at PT. XYZ can be improved in the future, and the number of job failures and non-productive time can be significantly reduced.

Fig. 4. Fishbone Diagram of 6 major causes of work errors at PT. XYZ

4.3.2 Measure Stage

The House of Risk is utilized as a tool for the ranking and prioritization of diverse types of risk events, based on data collected during the initial phases of risk assessment. Figure 5 showcases the incorporation of multiple factors within the House of Risk, encompassing the intensity of identified risk events, the frequency of occurrence of the risk agents, the correlation between the risk events and risk agents, and the Aggregate Risk Potential (ARP) value. The ARP value is a composite score that takes into account both the severity and likelihood of a risk event transpiring.

As depicted in Figure 5, there were a total of 21 identified risk events and 35 corresponding risk agents in the field. Among these, 6 risk events were identified as possessing severe impacts. Furthermore, within the pool of 35 risk agents, 12 were found to exhibit a high-level ARP, as expounded upon in Table 2, titled "Risk Agent List with the Highest ARP," and Figure 6, the "Pareto Chart of Risk Agent."

Fig. 5. House of Risk Analysis

The House of Risk effectively measure, manage and mitigate potential risks by identifying and prioritizing high-risk events as an input to the next DMAIC phase which is Analyze.

4.3.3 Analyze Stage

Based on the measured ARP data, it was possible to identify 12 dominant problem causes out of 35 risk agents. These results are presented in the Pareto diagram displayed in Figure 6 below.

Fig. 6. Pareto Chart of Risk Agent

As can be seen from the Pareto diagram, the highest risk factors must be addressed first, using preventive or mitigative measures, in accordance with the 80:20 rule. This means that the risk agent dominating 80% of the time must be addressed as a priority. Based on this approach, the 12 major problem causes were identified, and these findings were derived from the cumulative 80% ARP value, as presented in Table 2 below.

Table 2. Risk Agent List with the Highest ARP

<table>
<thead>
<tr>
<th>Rank</th>
<th>Code</th>
<th>Risk Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A3</td>
<td>Difficult to Understand Work Instruction</td>
</tr>
<tr>
<td>2</td>
<td>A6</td>
<td>Tendency to Modify Work Instructions</td>
</tr>
<tr>
<td>3</td>
<td>A7</td>
<td>Not Complying HSE</td>
</tr>
<tr>
<td>4</td>
<td>A5</td>
<td>Inappropriate Work Tools</td>
</tr>
<tr>
<td>5</td>
<td>A8</td>
<td>Differences in Understanding Work Instructions</td>
</tr>
<tr>
<td>6</td>
<td>A2</td>
<td>Not Following Work Instructions</td>
</tr>
<tr>
<td>7</td>
<td>A12</td>
<td>Inability to Complete the Workload</td>
</tr>
<tr>
<td>8</td>
<td>A13</td>
<td>Not Thorough in Work</td>
</tr>
<tr>
<td>9</td>
<td>A14</td>
<td>Non-compliance in Following the Policy</td>
</tr>
<tr>
<td>10</td>
<td>A19</td>
<td>Poor Material Handling</td>
</tr>
<tr>
<td>11</td>
<td>A15</td>
<td>Incomplete Permit Documents Related to Work</td>
</tr>
<tr>
<td>12</td>
<td>A23</td>
<td>Allowances Against Material Inspection Tests</td>
</tr>
</tbody>
</table>

4.3.4 Improve Stage

Based on the 12 risk agents indicated by the Pareto diagram, there are several treatment strategy plans in which can eliminate or reduce the emergence of risk agents. In the previous sub-chapter, were identified through the Pareto chart. From the risk agent levels identified in Analyze stage, several mitigation strategies are developed as shown in Table 3 to eliminate or reduce the emergence of risk agents.

Table 3. Mitigation Strategy for Selected Risk Agents
The list of mitigation strategies provided above offers solutions to address each selected risk agent. However, each mitigation strategy has a varying level of difficulty when it comes to field implementation. For instance, direct changes may be necessary to existing company system, and sufficient resources allocation to support mitigation strategies implementation, including human resources and finances.

Thus, mitigation strategies can be classified according to their degree of difficulty. After determining the difficulty scale, the effectiveness of each strategy is assessed by multiplying the correlation score with the Aggregate Risk Potential (ARP) to obtain the Total Effectiveness. The Effectiveness to Difficulty (ETD) ratio of the proposed treatment strategy is then calculated by dividing the Total Effectiveness by the Degree of Difficulty. The calculation of the ETD ratio uses equation (1) as shown below.

$$ETD_k = \frac{TE_k}{D_k}$$

The results of the calculation of the effectiveness to difficulty ratio ($ETD_k$) of the proposed mitigation strategy can be seen from Table 4 below. Table 4 displays the mitigation values to determine the most effective treatment strategy and the one that should be implemented first to reduce the probability of a risk agent. The company can select the handling strategy based on the ranking by referring to the ETD values in the table. The ranking shows the handling strategies that should be applied first.

According to Table 4, the handling strategies that should be implemented first are optimizing standard work instructions (P1), conducting job checklists (P4), conducting routine pre-job safety meetings (P3), and conducting standard work instruction campaigns (P6). The other strategies include regular HR training (P2), periodic audits (P5), improving the quality of breaks or break time (P7), improving the quality of material inspection (P8), and routine inventory (P9). Therefore, to address work failure issues or errors at PT. XYZ, it is necessary to quickly optimize the standard work instructions.

### 4.3.5 Control Stage

During the control stage, an evaluation is performed to determine the results of the optimized standard work instruction process. Internal audits are also conducted to monitor and update work instruction standards, revise or add work instruction standards, control the implementation of new work instruction standards, and ensure compliance with existing work instruction standards through observation and intervention. This
observation and intervention process is part of PT XYZ’s HSE (Health Safety Environment) program, which encourages employees to observe their environment and work to ensure that safety standards are met. If necessary, employees can intervene by providing suggestions, prevention, and improvements, which are then recorded and entered into the hub at PT XYZ.

Observation and intervention are part of a management system located on the hub or server owned by PT XYZ. The system includes all input and reports made by employees regarding any violations of the HSE in their work. By analyzing the data and reports from the server, the implementation of optimized standard work instructions can be controlled and evaluated based on employee input. Examples of employee observation and intervention reports can be seen in Figures 7, 8 and 9, respectively.

4.3.6 New Design Analysis of Standard Work Instructions

Through DMAIC, we can conclude that there are several improvements and developments of work instructions as follows:

1. Tools instructions were demonstrated in visual information (images)
2. PPE (Personal Protective Equipment) points are provided as employee comply the rule in activities or task being performed.
3. Warnings and additional information signs to avoid mistakes or work processes.
4. For each step performed, detailed explanation provided.
5. New Work Instruction Standard in Bahasa Indonesia should be demonstrated as it easier to understand for employees (operators and technicians)
6. Enactment of standardized work instructions for all Well Service segments throughout Indonesian Geomarket.

As the result, Fig.10 below show the new design of work instructions in Maintenance and Laboratory division.

5 Conclusion

In oil and gas company, health and safety procedure must be implemented in accordance to the company’s sustainable strategy. Especially a clear standardize work instructions to ensure the work processes carried out effective and efficiently. However, the study found that the existing standard work instructions were ineffective due to unclear instructions and frequent modifications based on the Absolute Risk Priority (ARP) Method. Leading it difficult to understand the work instructions.

In the Define stage of the DMAIC method, six major causes of work error problems were identified, including work instructions (methods), management, machines, personnel, materials, and measuring tools. At the Measure stage, risk management was carried out through House of Risk (HOR) analysis. In the Analyze stage, 12 types of problem sources were identified, with the most significant issues being work steps that were difficult to understand and tend to be modified. In the Improve stage, a series of problem mitigations were identified, with optimizing standard work instructions being ranked first. Finally, in the Control stage, verification testing was conducted through expert judgment.

Expert judgment was used to verify the proposed optimization of the Standard Work Instructions, which was found to be relevant to the issues that occur in the Well Service segment of PT XYZ’s sustainable strategy. The proposed Standard Work Instructions optimization was deemed representative and clear in its delivery. It is hoped that the draft Standard Work Instructions can be validated, reviewed, and updated annually to ensure their proper implementation. With consistency and cooperation from various parties in the Well Service segment, the draft Standard Work Instructions can
improve the quality and effectiveness of employees' work while upholding work safety principles. It can be concluded from the expert judgment review that the draft work instruction standard can be a solution to reduce work failures and errors. The Standard Work Instructions optimization project can significantly improve the quality of work instructions, making them easier to understand and less likely to be modified. The implementation of the Sustainable Standard Work Instructions optimization project can also increase employees' efficiency in carrying out their tasks. Furthermore, it can help improve work safety principles and reduce the risk of accidents in the workplace. Thus, ensuring the overall sustainability of the company's manufacturing production strategy.

In conclusion, the Standard Work Instructions used by PT XYZ were found to be less effective based on the ARP data processing. The Six Sigma approach with the DMAIC method was shown to be effective in optimizing the Standard Work Instructions. The proposed optimization of Standard Work Instructions was verified through expert judgment, which found it to be relevant, representative, and clear in its delivery. With annual validation, review, and updating, the Standard Work Instructions can be properly implemented, reducing work failures and errors, and improving work safety principles. The implementation of the Standard Work Instructions optimization project can significantly improve the quality of work instructions, employees' efficiency in carrying out tasks, and work safety in the Well Service segment of PT XYZ.

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