ANALYSIS OF LEAN SIGMA - DMAIC IMPLEMENTATION WITH ENVIROMENTAL CONSIDERATIONS IN OIL & GAS INDUSTRY (CASE STUDY: ONSHORE FIELD ABC TERMINAL FIELD – PT XYZ)

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Abstrak
Tujuan dari penelitian ini adalah untuk menganalisis penerapan kerangka perbaikan berkelanjutan berdasarkan metode Lean Sigma DMAIC (define-measure-analyse-improve-control), dengan mempertimbangkan lingkungan dalam menjaga keberlanjutan bisnis di industri minyak dan gas. Pendekatan tindakan penelitian dalam studi kasus digunakan untuk menggambarkan penerapan kerangka Lean Sigma - DMAIC yang diusulkan untuk meningkatkan kinerja operasional dan lingkungan dalam lingkungan industri minyak dan gas. Studi kasus menggambarkan penerapan siklus Lean Sigma – DMAIC untuk meningkatkan kualitas minyak mentah – produk Base sediment & water (BS&W) dan mengoptimalkan konsumsi energi dalam pengolahan minyak mentah. Setelah dilakukan perbaikan kualitas produksi minyak yang sebelumnya mengalami penyimpangan serta melakukan perbaikan dan efisiensi pada pabrik pengolahannya, maka pabrik pengolahan minyak ini dapat mencapai penghematan biaya operasional sebesar US$ 181,847.95 dan manfaat lingkungan dalam mengurangi emisi CO2 sebesar 1,685.81 ton (CO2 eq) dengan mengurangi konsumsi gas yang digunakan untuk memanaskan minyak mentah di pabrik pengolahan minyak.

Kata Kunci: Lean sigma, DMAIC, Perbaikan Berkelanjutan, Kelestarian Lingkungan.

Abstract
The objective of this research is to analyse the implementation of a sustainable improvement framework based on the Lean Sigma DMAIC (define-measure-analyse-improve-control) method, considering the environment in maintaining sustainable business in the oil and gas industry. The research action approach in a case study is used to illustrate the application of the proposed Lean Sigma - DMAIC framework to improve operational performance and the environment in the oil and gas industry setting. The case study illustrates the application of the Lean Sigma - DMAIC cycle to improve crude oil quality – Base sediment & water (BS&W) product and optimize energy consumption in the processing of crude oil. After improving the quality of oil production that previously experienced deviations and making improvements and efficiencies in the processing plant, this oil processing plant can achieve operational cost savings of US$ 181,847.95 and environmental benefits in reducing CO2 emissions by 1,685.81 tons (CO2 eq) by reducing the gas consumption used to heat crude oil in the oil treating plant.

Keywords: Lean sigma, DMAIC, Continues Improvement, Environment Sustainability.
INTRODUCTION

The development of the industrial world has surpassed the limits of what humans used to dream of. It all began with the industrial revolution that massively changed human civilization and had a significant impact on the social, economic, and cultural conditions of the world. These changes not only brought positive impacts, but also negative ones for the world (Syaputra, Pradhana, and Syamsuri 2022).

There has been a shift in the balance of nature, which potentially brings disasters for humans. The climate crisis and increasing levels of environmental degradation are becoming more and more worrying, forcing humans to take more responsibility in paying attention to and caring for the environment. The rise in environmental awareness among society has led to an increase in the expectations of customers regarding social and environmental performance. Globally, environmental problems are primarily caused by industrial activities (Jeremiah, Woldesenbet Beta, and Etim 2023). As a result, organizations have been compelled to change their approaches to managing operations and procedures. (Mishra 2022). The biggest issue today is directed towards the industrial world whose activities rely on fossil fuels and emit emissions that disturb the balance of nature.

PT. XYZ is one of the companies in the field of oil and natural gas exploration that has been operating for nearly 50 years in Indonesia. The challenge for the company is to manage its production and processing facilities, where the well production has significantly decreased, and the processing equipment is aging. Maintaining product quality becomes something very difficult where many design boundaries have been exceeded and have an impact on operating inefficiencies. This inefficiency has an impact on increasing emissions released into the environment.

The company's responsibility to the environment includes their efforts to manage emissions, which are seen as a crucial aspect of their operation strategy. This approach not only promotes sustainability but also enhances the company's competitiveness by ensuring that all stakeholders are satisfied (Samsul and Khair 2021). It’s recommended combining Green and Lean approaches to decrease environmental pollution, but their combination did not lead to the highest level of sustainable performance for organizations. To address this disparity, Six Sigma was introduced as a means of achieving this goal (Mishra 2022). DMAIC (define-measure-analyse-improve-control) methodology is utilized by six sigma, which is a data-based method aimed at minimizing mistakes and faults (Nascimento et al. 2020). Organizations around the world have had to modify their continuous improvement (CI) methodologies in order to achieve their environmental goals, as the ecological impact of their business processes has significantly decreased (Prashar 2020). Moreover, given the substantial investments made in process industries such as chemical plants, refineries, fertilizer units, and thermal power plants, the implementation of continuous improvement (CI) applications could result in significant operational advantages that contribute to their long-term economic viability (Prashar 2020).

The objective of this paper is to evaluating implementation of Lean Six Sigma DMAIC implementation and its effect on ABC Oil Processing Plant – PT. XYZ and the influence of its operations on environmental management. the paper will provide the literature review of the research, focusing on defect of its operation plant, and method of root cause finding using Cause-Effect Diagram. By analyzing operating conditions and finding the root cause using brainstorming, it is expected to be able to make the right strategic decisions and maintain the continuity of operations in the future.

Operations Management

Operation management is a set of activities aimed at creating or adding value in the form of goods and services by transforming inputs into outputs. The production of goods and
services is carried out and performed by all organizations/companies (Heizer et al., 2020). According to Slack (2013), Operations Management is the activity of managing resources that produce and deliver goods and services. The function of operations is a part of various functions in an organization, such as marketing, finance, and human resources. The operations function is responsible for the production or delivery of goods and services within an organization. This means that every organization engages in operational activities because all organizations produce goods and/or services. Management covers upstream to downstream operations by integrating, coordinating, and collaborating all elements of operations.

**Operation Strategy**

According to Schroeder (1989), the definition of operations strategy is a vision of the operations function that sets the overall direction or driving force for decision-making. Operations strategy involves a set of decisions that shape the long-term capabilities of the organization and contribute to the overall strategy by considering market needs and available operational resources (Slack, Lewis, 2020).

**Lean Six Sigma**

Lean Six Sigma is an approach that involves a team-based effort to enhance performance by systematically eliminating waste. It combines the principles of lean manufacturing/enterprise and Six Sigma to eradicate the eight types of waste: time, inventory, motion, waiting, overproduction, over-processing, defects, and unused skills (Atanas J P, Rodrigues C C, and Simmons 2016).

Lean Six Sigma is a data-driven methodology that aims to optimize business processes and maximize shareholder value. It accomplishes the issues by focusing on improving customer satisfaction, reducing costs, enhancing product and service quality, accelerating process speed, and increasing return on invested capital (George 2002). By using various statistical tools and techniques, Lean Six Sigma identify and eliminate process inefficiencies and defects, resulting in higher productivity, faster lead times, and better customer experiences. This approach helps organizations achieve sustainable growth and competitive advantage in today's dynamic business environment. Overall, LSS is a comprehensive approach that enables organizations to align their operations with customer needs, streamline their processes, and achieve higher levels of performance, efficiency, and profitability. According to (Atanas J P et al. 2016), Six Sigma's effectiveness lies in its systematic approach to utilizing tools and techniques that rely on data-driven decision-making.

According to (Sony 2017), Lean Six Sigma has been widely adopted as a technique in a variety of areas including health, education, manufacturing, services, etc.

**RESEARCH METHOD**

**The figure 1 shows how we planned to do this study step by step:**

The purpose of this research is to solve problems that arise or are being faced by the company. Direct field observation was used in the early stages of this research to pinpoint the problems. According to (Arumugam, Antony, and Douglas 2012), Observation is the most fundamental instrument that, when practiced and used effectively, can lead to revolutionary improvement. When the observations show operating parameters that begin to appear deviations, initial handling is carried out by discussing in a brainstorm with members of the production department. Furthermore, Brainstorming is conducted to focus on the discussion that was previously stated in the brainstorming session.

From the discussion session found concern regarding changes in the quality of production results and then develops towards the problem of plant efficiency which has
decreased marked by an increase in the coefficient of use of fuel gas which directly causes an increase in emissions released into the environment. The method used for handling these issues is implemented lean six sigma - DMAIC to identify waste & defect in the production operation. The synergies between lean production (LP) and six sigma principles to propose a lean six sigma (LSS) framework for continuous and incremental improvement in the oil and gas sector (Nascimento et al. 2020).

Figure 1. Methodology Flow Chart

Five phases in lean sigma – DMAIC applications:

1. Define

The researcher must identify the problem and research objectives in this phase. the use of a bottom-up approach, helps the process of problem identification and improvement to be faster which is carried out based on the parameters obtained from the production division. these parameters are in the form of Key Performance Indicators (KPI) that have been determined by the production division. Matters relating to key performance indicators (KPIs) from the production division will show the problems that arise.

2. Measure

After looking at the key performance indicators, the next step is to measure data related to operating parameters in accordance with the objectives in the define phase. Other process parameters were compared to determine the effectiveness of the processing plant. An approach to environmental considerations is incorporated to look deeper into the problems occurring in the processing plant.

3. Analyse

Fishbone diagram is the analytical tool to be used in this phase is by exploring problems that arise through brainstorming (Clark, 2011; Baumgartner, 2012).
Brainstorming is also carried out to sharpen the analysis stage to map the root of the problem.

4. Improve

In the improve stage, the implementation of the improvement process on the root of the problem is obtained with the aim of improving process performance and eliminating the causes of defects that arise. Continuous improvement by incorporating an environmental consideration approach to the processing process to ensure sustainable business processes.

5. Control

This phase aims to maintain the improvements that have been made that make performance binding to the process. The ideal solutions for lowering mean and variation are determined and confirmed in this phase (Nascimento et al. 2020).

Emphasizing problem solving with environmental considerations is a crucial thing to do today. This is to ensure sustainable business processes that require industry actors to contribute to maintaining environmental balance. Environmental sustainability is now one of the strategic imperatives for organizations that must be matched with conventional profitability and efficiency aims (Garza-Reyes 2015).

The goal of this study is to analyse the outcomes of lean six sigma implementation in the oil processing plant ABC Terminal at PT XYZ based on the formulation of the issues and contexts that have been highlighted above and where other scholars have conducted similar research, such as (Wahyudhi and Subroto 2017), (Banawi and Bilec 2014) and (Prashar 2020) in different sectors. This study used one indicator each for economic (cost savings in USD) and environmental (reduction in emission measured as tons of CO2 equivalent).

RESULT AND DISCUSSION

PT. XYZ, as one of the oil and gas companies in Indonesia whose facilities have been operating for more than 50 years, has a strong commitment to ensuring the quality of its petroleum products during the refining process at its facilities, conducting efficient operations, and reducing negative environmental impacts. By carrying out a good processing operation process by prioritizing product quality and good environmental management, namely by preserving natural resources in the processing process, it will maintain the continuity of business operations and maintain PT XYZ's corporate image in the eyes of stakeholders and the public. The study conducted by Gupta et al. (2021) shows that improving plant capability can enhance a company's competitiveness and productivity.

Related to the commitment of PT XYZ which is translated into a top-down strategy on product quality, operating efficiency and environmental control, a continuous evaluation process of operations is consistently carried out every year to monitor the operations of the processing process carried out.

Bottom-Up approach is also carried out to meet the expectations of the company's commitment. One of the implementations carried out is to involve employees at the operation level to be actively involved in finding, processing, or monitoring the ongoing operation process and providing input on innovations regarding the ongoing operation process. The
result of this form of implementation is the identification of processing operation problems at
one of the processing plants owned by PT. XYZ.

1. Define Phase

One of PT. XYZ's plants, namely the ABC terminal, experienced a decline in performance in 2019, with findings showing that the quality of processed products did not meet the established standards, and inefficient processing operations directly contributed to an increase in exhaust gas emissions. Based on the 2019 operational data of the processing plant, the annual average, as per monthly operational data, could not achieve the key performance indicator (KPI) of BS&W product quality ≤ 0.5%. The average annual achievement in 2019 of product quality was 0.67%

![Figure 2. Crude Oil Product Quality (KPI) Achievement – 2019](image)

From the results of the achievement of the product quality key performance indicator (KPI) above, it shows that there is a deviation in the operating process where the annual average of crude oil quality products does not meet the expected target of BS&W ≤ 0.5%. Achieving the quality of processed products is one of the measurements of the quality of the maintenance system and operating performance at PT XYZ. For this reason, it is important to conduct an in-depth evaluation of the operating processes that take place at the ABC terminal processing plant - PT XYZ.

2. Measure Phase

The parameters that will be measured are operating data in 2019 including Incoming Gross Liquid, water cut incoming liquid, net oil production and fuel gas consumption. This operating data will illustrate the performance of the processing plant.

In figure 4, it can be seen that the quality of incoming liquid entering the process is decreasing, this is indicated by the trend of higher watercut in incoming liquid.

The parameters net oil production and fuel gas consumption (figure 5 & 6) are parameters that will show the performance of the processing plant. These parameters will be calculated to obtain the value of the gas consumption coefficient required to produce 1 barrel of net oil. From the data calculation, it is found that in 2019 the coefficient value of fuel gas usage to produce 1 barrel of oil is 0.101 MSCF/Barrel.
Figure 3. Incoming Gross Liquid from Offshore

Figure 4. Incoming watercut liquid - 2019

Figure 5. Net Oil Production - 2019

Figure 6. Fuel Gas Consumption - 2019

Table 1. Production coefficient - 2019

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Gas</td>
<td>13279</td>
<td>11266</td>
<td>15939</td>
<td>16768</td>
<td>16993</td>
<td>14706</td>
<td>13968</td>
<td>12993</td>
<td>15843</td>
<td>11622</td>
<td>12872</td>
<td>15578</td>
</tr>
<tr>
<td>Net Oil</td>
<td>150001</td>
<td>140812</td>
<td>153721</td>
<td>149497</td>
<td>158517</td>
<td>158078</td>
<td>156986</td>
<td>156471</td>
<td>129364</td>
<td>150586</td>
<td>129842</td>
<td>135330</td>
</tr>
<tr>
<td>Fuel Consumption per Net Oil Product (MSCF/bbl)</td>
<td>0.083</td>
<td>0.088</td>
<td>0.103</td>
<td>0.112</td>
<td>0.107</td>
<td>0.112</td>
<td>0.100</td>
<td>0.095</td>
<td>0.122</td>
<td>0.078</td>
<td>0.099</td>
<td>0.115</td>
</tr>
</tbody>
</table>

0.101
The heating process is important in determining the quality of products in the crude oil processing. for this reason, the coefficient value in table 1 becomes an important factor to be considered in making ideas and implementing improvement solutions. The resulting solution must be in line with the environmental management considerations.

3. Analyze Phase

Fishbone diagram is a method used in the process of analysing the root causes of failure to achieve the desired product quality . The brainstorming process involves workers who are competent and directly responsible in the field (Sr. Supervisor Production & Analyst Field Operation) of the production division of PT XYZ to get the results of the fishbone diagram analysis (Banawi and Bilec 2014). The brainstorming process is attended by 6 people to find the root cause of the problem from each condition from each side such as human, method, material, machine, measurement, and environment.

![Fishbone Diagram](image)

Figure 7. Fishbone diagram – product quality deviations

4. Improve Phase

After the root of the problem is seen in the fishbone diagram analysis, identification of improvement solutions will be carried out. This filtering of solutions is done with several criteria and the main requirement is "whether the solution is feasible or not". Brainstorming process was conducted to select possible solutions for implementation. The selection of these solutions is as shown in table 2 below:

<table>
<thead>
<tr>
<th>No</th>
<th>Problem</th>
<th>Caused</th>
<th>Alternative Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Actual daily production that cannot be delayed</td>
<td>country daily production reporting</td>
<td>No Solution. Because this is a compliance set by the government</td>
</tr>
<tr>
<td>2</td>
<td>Slow process quality improvement response</td>
<td>many processes are done manually</td>
<td>Upgrade equipment, but it is difficult to do because it requires a large investment value. <strong>The improvement that can be made is to change the operation method for the production process to get a more efficient solution.</strong></td>
</tr>
<tr>
<td>3</td>
<td>Abnormal condition at process system</td>
<td>Aging equipment</td>
<td>Upgrade equipment. but it is difficult to do because it requires a large investment value. <strong>The improvement that can be made is to change the operation method</strong></td>
</tr>
</tbody>
</table>
4. Gross incoming liquid with high watercut in the mature field

5. Operating methods that have not been adapted to changes in actual parameters
   - Well condition at mature field
   - Lack of Innovation & initiatives
   - Brainstorming and socialization of continuous improvement processes and strong emphasis on KPI targets

6. Crude Heater is not working properly
   - High water content in process input

   Un-optimal separator performance
   - Aging equipment
   - Upgrade equipment, but it is difficult to do because it requires a large investment value.
   - The improvement that can be made is to change the operation method for the production process to get a more efficient solution.

From brainstorming the selection of alternative solutions, the solutions obtained lead to improvements/changes in operating methods. The solution is not an absolute solution that can overcome a problem, but the solution can be done and plays a role in the improvement process in the majority of aspects that cause problems.
As seen in Figure 8, the change in operating methods brought improvements in product quality so that it reached the target according to the key performance indicator. The key performance indicator is crude oil quality products containing BS&W ≤ 0.5%. The annual average in the 2020 period, where the implementation of continuous improvement - DMAIC was carried out, obtained crude oil quality containing BS&W 0.41%.

5. Lean Evaluation

As seen in Figure 8 where changes in operating methods are made to overcome product quality problems, this solution also has a positive impact on the use of fuel gas which has implications for operating performance in the 2020 period. A decrease in the production coefficient of fuel gas use per net barrel of oil produced has implications for saving production costs and reducing exhaust emissions. A decrease in the coefficient of gas fuel usage per net barrel of oil produced from 0.101 MSCF/barrel in 2019 to 0.082 MSCF/barrel in 2020.
Process Flow modification (Improvement of operation method)

Energy saving in oil processing system = 25.684 MMSCF
Annual Economic benefit = 25.684 X 1,180 X 6 = US$181,847.96
(Heating value of gas 1,180 MMBTU/MMSCF & fuel gas price at US$6/MMBTU)
Annual Environmental benefits = 25.684 MMSCF = 1,685.81 Ton CO₂ eq

The elimination of rework processes provides significant savings in reducing production costs and increasing environmental benefits. Continuous improvement processes based on environmental considerations will continue to maintain business continuity and environmental sustainability in the production/operation process of industrial companies.

**CONCLUSION**

The implementation of the lean Sigma framework in overcoming the problems that occur in the ABC terminal at PT XYZ has two positive impacts in terms of economy and environmental management based on the analysis and discussion conducted in this study. A list of benefits could include, but is not limited to:
a. The application of lean sigma methodology can be applied to the oil and gas industry to improve or enhance quality, improve operating efficiency and environmental performance (Mishra 2022).

b. After making improvements and innovations to the crude oil processing at ABC terminal - PT XYZ through the concept of lean sigma quality management, there was an improvement in the quality of crude oil processed. The results of the implementation of improvement ideas obtained through the process of changing operating methods by adjusting to the actual conditions of existing operating parameters provide improved performance on the parameter Fuel gas consumption per net oil product.

c. There are several factors that cause a decrease in the quality of processing performance or not achieving the key performance indicator (KPI) of the quality of Crude oil processing results in ABC terminal - PT XYZ, such as: input material parameters (liquid from mature oil wells at offshore fields) containing high base sediment & water (BS&W), old processing equipment (has been operating for approximately 50 years), processing methods that are no longer relevant with changes in parameters that are different from the initial design.

d. The activities of improvement and innovation have positive implications, such as the improvement in product quality that meets the set KPI targets and the increased efficiency in the processing process, indicated by a decrease in the coefficient of fuel gas usage per barrel of crude oil produced. This increased efficiency in processing has further positive impacts, such as decreased production costs and reduced emissions of exhaust gases. These outcomes have managerial implications, including financial benefits and a good company image. The improvements and innovations have resulted in cost savings of $181,847.95 in operational expenses and a reduction of greenhouse gas emissions of 1,685.81 tons (CO2 Eq).

The main limitation of this study is that the research only centred on one processing site in the company. Nonetheless, the studies adopted gave us an overview of the application of the Lean sigma framework in various industrial fields. Further research should investigate the potential and impact of implementing Lean Sigma methods at other company-owned sites or processing plants of other oil and gas companies.

REFERENCES


