# DEVELOPMENT OF A SUSTAINABLE LEAN COMPETITIVE STRATEGY IN A WATER PUMP COMPANY

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## ABSTRACT

The manufacturing industry is currently experiencing a shift towards sustainability-driven practices and principles. Company X is one of those who want to improve their competitiveness in the manufacturing industry by implementing sustainability. However, this company experiences obstacles in its production process because production targets still need to be achieved owing to product defects that average 8.97%. This study used the sustainable lean manufacturing approach to help the company to achieve more competitive goals by reducing waste and pollution and creating more efficient production processes. The tools used in this research were process activity mapping (PAM), sustainable value stream mapping (SVSM), and the sustainability index (SI). Based on calculations with sustainability indicators, the company's SI results amounted to 183%. The proposed improvements were given to improve the company's efficiency and to reduce its SI. After repairs had been made, the SI value was reduced to 118%. With the improvement in that value, production efficiency has also improved: the process cycle efficiency (PCE) value has become 90.49%, which means that the company's production process has become more efficient.

## OPSOMMING

Die vervaardigingsbedryf ervaar tans 'n verskuiwing na volhoubaarheidgedrewe praktyke en beginsels. Maatskappy X is een van dié wat hul mededingendheid in die vervaardigingsbedryf wil verbeter deur volhoubaarheid te implementeer. Hierdie maatskappy ondervind egter struikelblokke in sy produksieproses omdat produksieteikens bereik moet word weens produkdefekte wat gemiddeld 8,97% is. Hierdie studie het die volhoubare skraal vervaardigingsbenadering gebruik om die maatskappy te help om meer mededingende doelwitte te bereik deur afval en besoedeling te verminder en meer doeltreffende produksieprosesse te skep. Die instrumente wat in hierdie navorsing gebruik is, was prosesaktiwiteitkartering (PAM), volhoubare waardestroomkartering (SVSM) en die volhoubaarheidsindeks (SI). Op grond van berekeninge met volhoubaarheidsaanwysers het die maatskappy se SI-resultate 183% beloop. Die pVoorgestelde verbeterings is gegee om die maatskappy se doeltreffendheid te verbeter en sy SI te verminder. Nadat herstelwerk gedoen is, is die SI-waarde tot 118% verminder. Met die verbetering in daardie waarde het produksiedoeltreffendheid ook verbeter: die prosessiklusdoeltreffendheid (PCE) waarde het 90,49% geword, wat beteken dat die maatskappy se produksieproses doeltreffender geword het.

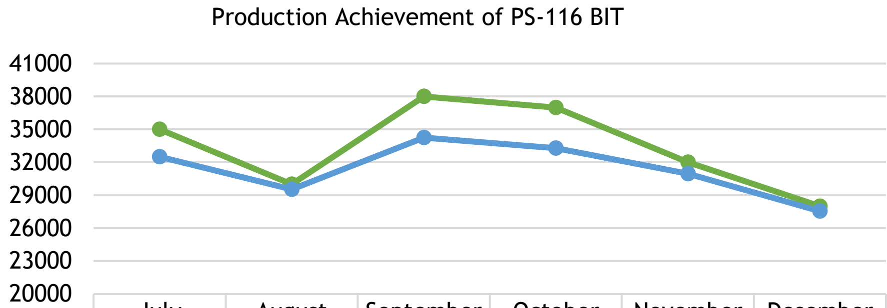
## 1. INTRODUCTION

### 1.1. Background

The rapid development of industry worldwide, especially in the manufacturing sector, has required every company to increase its productivity in order to compete. Along with industrial development, environmental problems are also increasing; so current industrial competition does not only focus on economic factors: companies must also be responsible for the environment and society [1]. Sustainability has now become a concept that must be carried out as necessary to maintaining a better life; therefore, companies worldwide have begun to focus on sustainability. A strategy that could help companies to achieve sustainability is the competitive manufacturing strategy (CMS). This strategy could help companies to improve their competitiveness by maintaining their production and reducing pollution and production waste [2]. There are five strategies in CMS: complexity, lean, agility, remanufacturing, and recycling [3].

Sari *et al.* [2] stated that a lean production system is one of the powerful tools that enable companies to enhance their sustainability performance. Implementing lean manufacturing helps companies to increase the added value of their products by reducing costs and increasing profits through minimising waste in their production process [4]. Lean production implements lean manufacturing principles to improve company performance by reducing the waste and variability that occurs in the manufacturing process [5]. Some previous studies have implemented the lean production system approach to enhance sustainability performance [6, 7, 8, 9]. This study follows a similar approach.

This research was conducted at Company X, focusing on the production process of the PS-116 BIT water pump. The company wanted to increase its competitiveness in the manufacturing industry by starting to focus on sustainability. To become a sustainable company, the production process must consider the economic, social, and environmental aspects that underlie sustainability. Companies must be responsible for their use of resources and reduce waste and pollution. However, Company X still needed to work on its production process in the light of unachieved production targets. Figure 1 shows the achievement of its PS-116 BIT production from July to December 2021.




| | July | August | September | October | November | Desember |
|---|---|---|---|---|---|---|
| Demand | 35000 | 30000 | 38000 | 37000 | 32000 | 28000 |
| Production | 32502 | 29550 | 34254 | 33280 | 30956 | 27550 |

**Figure 1: Production achievement**

Based on the production achievement data from July to December 2021 (Figure 1), the company's production had still to reach its planned monthly targets. According to interviews with the head of the company's production, followed by observations in the field, there were defects in the production process. Table 1 shows the defect data from July to December 2021.

Table 1: Defects for July-December 2021

| Month | Defects (units) | Production (units) | Percentage |
|---|---|---|---|
| July | 2450 | 32502 | 7.54% |
| August | 2100 | 29550 | 7.11% |
| September | 3060 | 34254 | 8.93% |
| October | 4100 | 33280 | 12.32% |
| November | 3300 | 30956 | 10.66% |
| December | 2000 | 27550 | 7.26% |
| **Total** | **17010** | **188092** | **8.97%** |

According to the defect data In Table 1, in six months the company produced 17 010 defects out of 188 092 units. The average monthly percentage of defects during that period was 8.97%, and occurred in the final and semi-finished products. If there is a defect in the product, it must be reworked; but that requires additional time, energy, raw materials, and labour. By reworking defective products, operators must repair the defects in them; production costs increase owing to the need for additional raw materials and labour, and energy consumption and pollution increase through the use of machines. Therefore, the existence of a defect can cause economic, social, and environmental losses. These problems can hinder the value of the company's sustainability index (SI); so a tremendous effort is required to achieve sustainability.

### 1.2. Formulation of the problem

The problem found in Company X was that production fell short of the planned monthly targets, indicating a need for improvement in the production process. Moreover, based on the interview results, it was found that the average defect rate was 8.97%. The problem related to data defects in the company's final and semi-finished products, leading to the need to rework the defective products. This rework entails additional time, energy, raw materials, and labour, thus increasing the production costs. Moreover, the use of machines during rework leads to increased energy consumption and pollution. The existence of defects not only results in economic losses, but also has social and environmental implications. These issues can impede the company's SI, necessitating significant efforts to achieve sustainability.

### 1.3. Research objective

The objective of this research was to design sustainable lean manufacturing in Company X with the following steps:

1. Identifying waste in the PS-116 BIT production process.
2. Calculating the SI to measure the level of sustainability of the company.
3. Providing suggestions to minimise waste by using a sustainable lean manufacturing approach.
4. Calculating the SI after improvements have shown an increase in production efficiency.

## 2. RESEARCH METHODOLOGY

The research was conducted using a sustainable lean manufacturing approach. There were four stages in this research. The first stage was carried out by collecting data through interviews with the head of production and using the company's historical data. The second stage was to perform data processing by identifying waste and value added (VA), necessary non-value added (NNVA), and non-value added (NVA) activities using process activity mapping (PAM), calculating manufacturing lead time (MLT) and process cycle efficiency (PCE), making current SVSM mapping using sustainability indicators, and measuring the company's SI. The third stage was to analyse and provide suggestions for improvements. The fourth stage was to map the future SVSM and to calculate the SI value, which was the company's condition after improvements.

## 3. ANALYSIS AND DISCUSSION

### *3.1.1. Process activity mapping*

Lean is an action taken to reduce non-value-added operations in the production process and to increase the value added to a product for customer satisfaction (customer value) [10]. The application of lean enables companies to improve their processes by increasing production efficiency, improving product quality, reducing costs, time, and resources consumed, and providing a better working environment. Lean has a positive impact on employee performance because it enhances teamwork. The human factor – the workers – plays a critical part in implementing lean by ensuring good communication and collaboration among workers to attain the same goals. Lean depends on the tools that are used to achieve the goals [11].

Process activity mapping (PAM) is a tool used in lean to map the flow of production activities and to determine the value added (VA), necessary non-value added (NNVA), and non-value added (NVA) activities [12]. VA activities are those in the production process flow that provide added value. This means that the activities that are carried out provide benefits for consumers. NNVA activities in the production process flow do not provide added value. This means that the activities are considered necessary but that consumers do not get added value. NVA activities are those that do not provide added value. Consumers do not get added value from them, so they need to be reduced or eliminated [13].

PAM can be used to identify the waste contained in every production process [12]. Waste is divided into eight types: overproduction, inventory, defects, excess processing, waiting, underutilised employees, excess motion, and transportation [3]. The activities in PAM are grouped into operation, transportation, inspection, storage, and delay [12]. Table 2 summarises PAM.

**Table 2: Process activity mapping – summary**

| Information | Number of activities | Activities percentage | Amount of time (s) | Percentage of time |
|---|---|---|---|---|
| **Activity type** | | | | |
| Operation | 42 | 66% | 4 084.65 | 82% |
| Transportation | 9 | 14% | 149.71 | 3% |
| Inspection | 8 | 13% | 180.85 | 4% |
| Storage | 2 | 3% | 24.51 | 0.5% |
| Delay | 3 | 5% | 534.78 | 11% |
| **Activity category** | | | | |
| VA | 29 | 45% | 3 940.14 | 79% |
| NNVA | 28 | 44% | 414.27 | 8% |
| NVA | 7 | 11% | 620.09 | 12% |
| **Waste type** | | | | |
| Defect | 3 | 30% | 34.47 | 5% |
| Overproduction | 0 | 0% | 0 | 0% |
| Waiting | 3 | 30% | 534.78 | 82% |
| Nonutilised talent | 0 | 0% | 0 | 0% |
| Transportation | 0 | 0% | 0 | 0% |
| Inventory | 0 | 0% | 0 | 0% |
| Motion | 0 | 0% | 0 | 0% |
| Excess processing | 4 | 40% | 85.31 | 13% |

The PS-116 BIT water pump production process has eight processes: press, welding, treatment, drying, motor assembly, painting, pump assembly, and packing. Each process has some activity. The total activity in the production process of the PS-116 BIT water pump is 64 activities. Based on the summary of the PAM, there were 29 VA activities with a total time of 3 940.14 seconds, 28 NNVA activities with a total time of 414.27 seconds, and seven NVA activities with a total time of 620.086 seconds. The types of waste found in the PS-116 BIT production process, based on Table 2, were defects, waiting, and excess processing. NVA and waste activities could be eliminated by providing suggestions for improvements to make the production process more efficient.

Manufacturing lead time (MLT) is the total time required to produce a product from raw materials to finished goods. The amount of time of VA, NNVA, and NVA was used to calculate the MLT value, which was 4 974.496 seconds. Process cycle efficiency (PCE) is a calculation to determine the level of efficiency of a company's production process. The PCE value was obtained by dividing the value added time (VAT) by the MLT, yielding a value of 79.21%. The greater the PCE value, the more efficient the production process is.

### 3.2. 3R analysis (reuse, reduce, recycle)

3R analysis is carried out to identify the implementation of the 3R strategy in a company. Company X had started to implement sustainability by introducing the 3R strategy. Based on Table 3 of the 3R analysis at the company, the 3R activities that it had carried out were reuse and recycle in the welding and treatment processes. In the welding process, the company had implemented the concept of reusing scrap left over from the turning process by selling it to third parties. In the treatment process, the concept that was applied was recycling: the waste produced in the form of water containing chemicals was processed so that the water to be disposed of did not harm the environment.

**Table 3: Company 3R analysis**

| Process | Reduce | Reuse | Recycle | |
|---|---|---|---|---|
| **Welding** | | □ | | Scrap lathe production will be collected and sold for recycling |
| **Treatment** | | | □ | Wastewater from production residues containing chemicals will be processed so that it does not have a negative impact on the environment |

### 3.3. Current sustainable value stream mapping

Sustainable value stream mapping (SVSM) is a method used to map sustainability in production lines. SVSM is a value stream mapping (VSM) method developed by adding social and environmental aspects [14]. The developed future SVSM could provide a solution by eliminating waste in the production process flow to improve company performance [1]. SVSM is used as a measuring tool to identify inefficient activities, measured using lean and sustainable manufacturing indicators. Using SVSM can help companies to improve their performance in every process [15]. In SVSM mapping, several indicators are selected to calculate the SI value. Table 4 shows the indicators of sustainable value stream mapping and the SI.

**Table 4: Sustainability indicators**

| Authors | Economic | | | | Social | | | | | Environmental | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E4 | S1 | S2 | S3 | S4 | S5 | N1 | N2 | N3 | N4 | N5 |
| Rahman *et al.* (2022) [16] | | | □ | □ | □ | | □ | | □ | □ | | □ | | |
| Marie *et al.* (2022) [8] | □ | □ | | □ | □ | | □ | □ | | □ | □ | □ | | |
| Sari *et al.* (2022) [7] | □ | □ | □ | | □ | □ | | | □ | | □ | □ | | |
| Marie *et al.* (2022) [6] | □ | □ | | □ | | □ | □ | □ | □ | □ | □ | □ | □ | □ |

| Authors | Economic | | | | Social | | | | | Environmental | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **E1** | **E2** | **E3** | **E4** | **S1** | **S2** | **S3** | **S4** | **S5** | **N1** | **N2** | **N3** | **N4** | **N5** |
| Atoillah and Hartini (2021) [1] | □ | □ | | | □ | □ | | | □ | □ | | | | |
| Sari *et al.* (2021) [2] | □ | □ | | | □ | □ | □ | □ | □ | | □ | □ | | |
| Marie *et al.* (2020) [9] | □ | □ | | | □ | □ | | | □ | □ | | □ | | |
| Hartini *et al.* (2020) [17] | □ | □ | □ | □ | □ | | □ | □ | □ | □ | □ | □ | | |
| Gholami *et al.* (2020) [18] | □ | | □ | | □ | | | | □ | | □ | □ | | |
| Djatna and Prasetyo (2019) [19] | | □ | | | □ | | | | | □ | | | □ | □ |
| Kusrini and Primadasa (2018) [15] | □ | | □ | | □ | □ | □ | □ | | □ | □ | □ | □ | □ |
| Kishawy *et al.* (2018) [20] | | | □ | | □ | | | | □ | □ | □ | □ | □ | □ |
| Hartini *et al.* (2018) [21] | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Huang and Badurdeen (2017) [22] | | | □ | | | □ | | | □ | □ | □ | □ | | |
| Garbie (2016) [3] | □ | □ | □ | | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| **Selected indicator** | □ | □ | | | | □ | □ | □ | | □ | □ | □ | | □ |

**Economic**: Time$^{E1}$, Quality$^{E2}$, Cost$^{E3}$, Inventory$^{E4}$

**Social**: Physical work: Activity with risk and lost workday$^{S1}$, Work environment: Noise and lighting level$^{S2}$, Satisfaction level$^{S3}$, Employee training$^{S4}$, Health level$^{S5}$

**Environmental**: Material consumption$^{N1}$, Waste recycling$^{N2}$, Energy consumption$^{N3}$, Waste water consumption$^{N4}$, Environmental standard compliance$^{N5}$

Selected indicators were used in SVSM and the SI calculation to follow the company's condition. SVSM has a traffic light system that shows the condition of a company. The red traffic light indicator indicates a critical condition; the yellow indicates a warning; and the green indicates a good condition. The traffic light system on the indicators of time, quality efficiency, employee training, satisfaction level, material consumption, wastewater recycling, and standard environmental compliance can be said to have a critical condition indicated in red if it has a value of 0% to 60%, has a warning condition shown in yellow if it has a value between 61% to 90%, and has a good condition shown in green if it has a value between 90% to 100% [13]. The noise level indicator has a red traffic light if the noise level is greater than 85 dB, yellow if the noise level is between 80 dB to 85 dB, and green if the noise level is less than 80 dB. [12]. The energy consumption indicator has a red traffic light if the energy consumption level is more than 200 000 kWh, yellow if the energy consumption is between 190 000 kWh and 200 000 kWh, and green if the energy consumption is less than 190 000 kWh. The primary energy consumption classification was obtained based on interviews with company employees. Table 5 shows the formula for calculating the value of each indicator.

'Current SVSM' is a mapping carried out on the company's current condition. SVSM explains the flow of the production process, and shows the number of operators, VA, NNVA, and NVA times. SVSM also shows the problems in each workstation, which the Kaizen Burst and the achievement of each indicator illustrate. Using SVSM with a traffic light can make it easier to describe the achievements of each indicator.

**Table 5: Indicator value calculation**

| Factor | Indicator | Input | | Value | Formula | |
|---|---|---|---|---|---|---|
| Economic | Time (%) | VAT | Value added time | 10.70 | TE = (VAT/TT) x 100 | 18.05 |
| | | TT | Total time | 59.28 | | |
| | Quality efficiency (%) | ND | Number of defects | 17 010 | QE = (1-(ND/TP)) x 100 | 90.96 |
| | | TM | Total product | 188 092 | | |
| Social | Noise level (dB) | | | | | 85.75 |
| | Employee training (%) | NT | Number of topic training | 7 | ET = (NT/NE) x 100 | 70 |
| | | NE | Number of topics | 10 | | |
| | Satisfaction level (%) | TO | Number of employee turnover | 21 | SE = (1-(TO/NE)) x 100 | 97.53 |
| | | NE | Number of employees | 850 | | |
| Environmental | Material consumption (%) | VAM | Value added material | 41 991.56 | ME = (VAM/TM) x 100 | 87.48 |
| | | TM | Total material | 48 000 | | |
| | Energy consumption (kWh) | | | | | 199180.8 |
| | Waste water recycling (%) | WR | Waste recycling | 400 | WE = (WR/TW) x 100 | 44.44 |
| | | TW | Total waste | 900 | | |
| | Environmental standard compliance (%) | | | | | 70 |

Based on the current SVSM mapping in Figure 2, the Kaizen Burst showed problems at several workstations: press, welding, treatment, drying, motor assembly, and pump assembly. The press workstation had a problem in the form of a high noise level. The welding workstations had problems with waste defects, waiting, transportation, and high noise levels. The treatment workstation had a problem in the form of waste waiting, while the problems at the drying workstations were waste waiting and transportation. The motor assembly workstations needed help with excess waste processing and high noise levels; and at the pump assembly, the problems were waste defects, excess processing, and high noise levels.

The traffic lights on SVSM were red and yellow, indicating that the indicators were below the target. Figure 2 shows that the red colour was found in the noise level and water waste recycling. High noise levels were found in the press, welding, motor assembly, and pump assembly workstations at more than 85 dB. The company's wastewater recycling rate was still low, producing as much as 900 litres of wastewater from the production process. The company can process as much as 400 litres wastewater; so its wastewater recycling efficiency was at 44.44%.

Based on Figure 2, the yellow colour was found on time, quality efficiency, employee training, material consumption, energy consumption, and standard environmental compliance. The value of the time indicator was 61.10%, the average time efficiency at eight workstations. The higher the time efficiency, the more efficient the production process is. The quality efficiency indicator was 90.96%, showing the level of production quality. The greater the quality efficiency, the fewer defects are produced. The employee training indicator was 70%, which showed that the company had successfully conducted training to improve employee performance. Material consumption was at 87.48%, showing the company's efficiency in using raw materials; so it only produced a small amount of scrap.

The energy consumption indicator of 199 180.8 kWh showed the company's energy consumption used during production. The standard environmental compliance of 70% indicated the company's compliance with environmental standards. Figure 2 shows the current SVSM mapping.

### 3.4. The calculation of the sustainability index

The SI calculation assesses a company's sustainability level in carrying out its production. The value of the SI covers three aspects of sustainability: economic, social, and environmental. Calculating the SI uses indicators from each aspect previously described in SVSM above. The SI for the economic aspect was 155%, for the social aspect 170%, and for the environmental aspect 265%. The overall SI was 185%, which indicated that the company had to make 1.85 times the effort to achieve sustainable conditions according to the target. Table 6 shows the calculation of the company's SI.

**Table 6: Sustainability index**

| Aspects | Indicator | Performance measures | Performance metrics | | Value of change | SI | | Vector eigen | Overall SI | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Existing | Target | | | | | | |
| **Economic** | E1 | Time (%) | 61.10 | 80 | 18.90 | 1.55 | 155% | 0.62 | 1.83 | 183% |
| | E2 | Quality efficiency (%) | 90.96 | 100 | 9.04 | | | | | |
| **Social** | S1 | Noise level (dB) | 85.75 | 85 | 0.75 | 1.70 | 170% | 0.14 | | |
| | S2 | Employee training (%) | 70 | 100 | 30 | | | | | |
| | S3 | Satisfaction level (%) | 97.53 | 99 | 1.47 | | | | | |
| **Environ-mental** | N1 | Material consumption (%) | 87.48 | 95 | 7.52 | 2.65 | 265% | 0.24 | | |
| | N2 | Energy consumption (kwh) | 199 180.80 | 189 221.76 | 9 959.04 | | | | | |
| | N3 | Waste water recycling (%) | 44.44 | 75 | 30.56 | | | | | |
| | N4 | Environmental standard compliance (%) | 70 | 90 | 20 | | | | | |

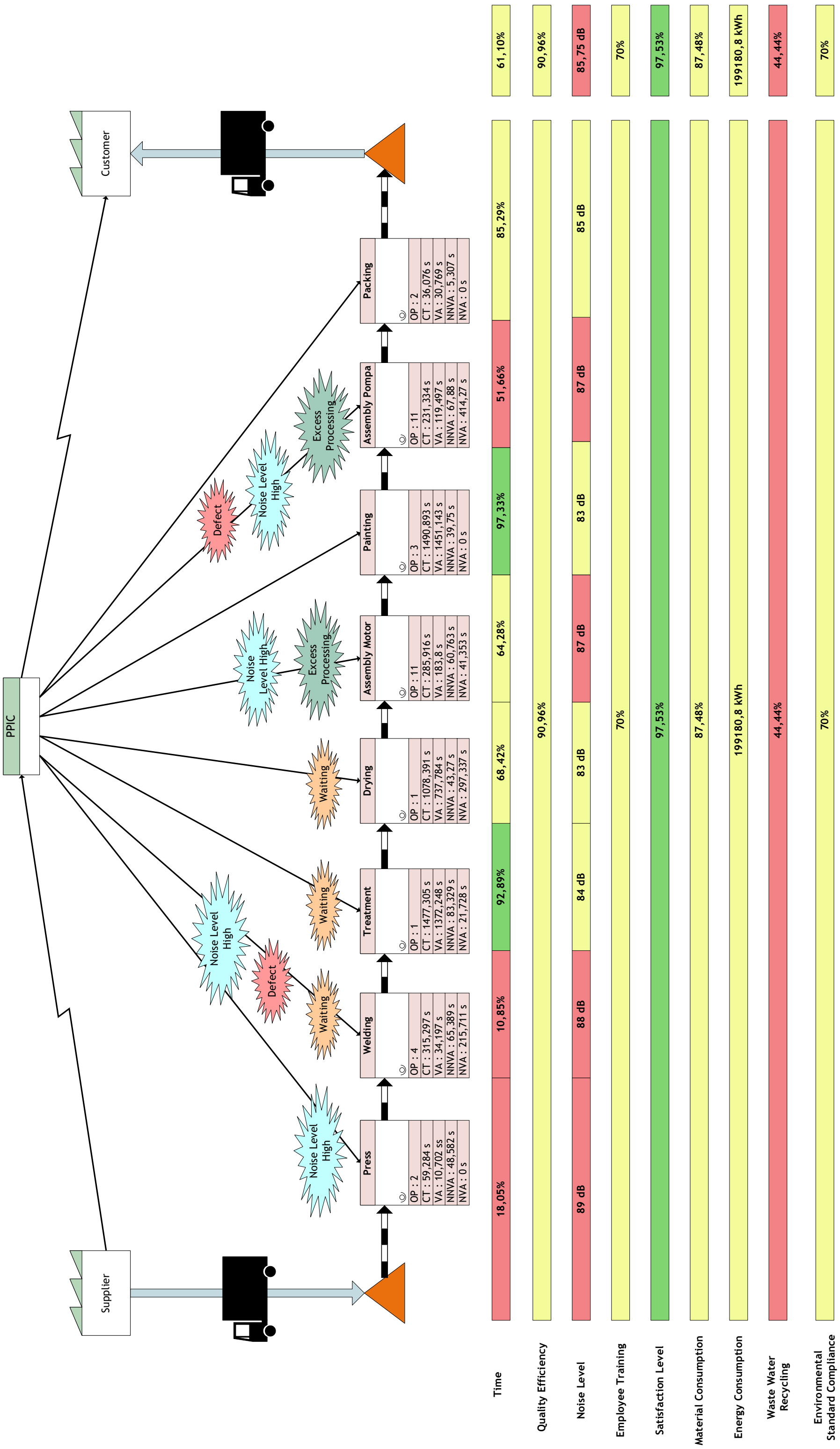



**Figure 2: Current sustainable value sream mapping**

### 3.5. Proposal for improvement

The proposal for improvement was determined after identifying the problem. Then the analysis results, which included the proposal based on the problem identification, were given to the company in order to increase the PCE value and to improve its SI. The proposed improvements also supported the company's achievement of the SDG goals – in particular, the third, fourth, and twelfth SDGs. The third SDG, good health and welfare, was achieved by proposing that PPE earplugs be procured to reduce noise levels on the production floor. The fourth SDG, quality education, was achieved by regular employee training. The twelfth SDG, responsible consumption and production, could be achieved by reducing waste defects, waiting, and excess processing, by implementing the 3R strategy, and using a water treatment plant to treat production waste to avoid a negative environmental impact. Table 7 shows the proposed improvement for each aspect.

**Table 7: Proposed improvements**

<table>
<tr><th>Aspects</th><th>Problem</th><th>Causes</th><th>Improvements</th><th>SDGs</th></tr>
<tr><td rowspan="10">Economic</td><td rowspan="6">Quality efficiency (waste defect)</td><td>Operators are not thorough</td><td rowspan="2">SOP construction</td><td rowspan="10">SDG 12</td></tr>
<tr><td>Unreliable operators</td></tr>
<tr><td>Changes in voltage and current</td><td>Provisions for automatic breakers (Poka Yoke)</td></tr>
<tr><td>The operator needs a lot of time in the welding process</td><td>Addition of a timer to the machine (Poka Yoke)</td></tr>
<tr><td>Gross components</td><td>Addition of air blow gun</td></tr>
<tr><td>Operators do other work</td><td rowspan="2">Review the number and placement of operators</td></tr>
<tr><td rowspan="2">Time (waste waiting)</td><td>A limited number of operators</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="2">Time (waste excess processing)</td><td rowspan="2">Repeated inspections</td><td>Loss of activity</td></tr>
<tr><td>Activity merging</td></tr>
<tr><td rowspan="3">Social</td><td rowspan="2">Noise level</td><td>There is no OHS for the provision of PPE</td><td rowspan="2">Procurement of earplugs</td><td rowspan="2">SDG 3</td></tr>
<tr><td>Noise level above 85 dB</td></tr>
<tr><td>Employee training</td><td>Did not participate in training according to competency targets</td><td>Conducting regular training</td><td>SDG 4</td></tr>
<tr><td rowspan="5">Environment</td><td>Energy consumption</td><td>A high number of defects</td><td>Reducing waste defects</td><td rowspan="5">SDG 12</td></tr>
<tr><td rowspan="2">Material consumption</td><td>There are remaining raw materials from production</td><td rowspan="3">Implementation of the 3R strategy (reuse, reduce, recycle)</td></tr>
<tr><td>There is no processing of waste and scrap</td></tr>
<tr><td rowspan="2">Waste water recycling</td><td>Wastewater treatment by companies only 44.44%</td></tr>
<tr><td>Limited wastewater treatment capacity</td><td>Use of water treatment plant</td></tr>
</table>

## 3.6. Conditions after improvement

### *3.6.1. Process activity mapping*

The conditions after improvement would be the company's conditions if the proposed improvements were implemented. PAM, after improvement, would have 57 activities from 64 activities. Based on Table 8 PAM, after the improvements were carried out, four eliminated NVA activities were eliminated. The activity was eliminated because it were repetitive inspection activities. In addition to eliminating activities, there was a merger of activities in the pump assembly process. Other omitted activities were waiting for welding, treatment, and painting activities.

**Table 8: Summary of process activity mapping after improvements**

| Information | Number of activities | Activities percentage | Amount of time (s) | Percentage of time |
|---|---|---|---|---|
| **Activity type** | | | | |
| Operation | 41 | 72% | 4058.237 | 93% |
| Transportation | 9 | 16% | 149.707 | 3% |
| Inspection | 5 | 9% | 121.955 | 3% |
| Storage | 2 | 4% | 24.511 | 1% |
| Delay | 0 | 0% | 0 | 0% |
| **Activity category** | | | | |
| VA | 29 | 51% | 3940.14 | 90% |
| NNVA | 28 | 49% | 414.27 | 10% |
| NVA | 0 | 0% | 0 | 0% |
| **Waste type** | | | | |
| Defect | 0 | 0% | 0 | 0% |
| Overproduction | 0 | 0% | 0 | 0% |
| Waiting | 0 | 0% | 0 | 0% |
| Non-utilised talent | 0 | 0% | 0 | 0% |
| Transportation | 0 | 0% | 0 | 0% |
| Inventory | 0 | 0% | 0 | 0% |
| Motion | 0 | 0% | 0 | 0% |
| Excess processing | 0 | 0% | 0 | 0% |

An improvement to waste made NVA activity redundant because it had affected the efficiency of the company's production process; the removal of NVA increased the production process's efficiency. Improvements to the economic aspect reduced waste in the form of defects, waiting, and excess processing so that the production process became more effective. After improvement, MLT decreased to 4 354.41 seconds and PCE increased to 90.49%. An increase in PCE indicates that the production process is more efficient. Table 9 shows a comparison of the times before and after the improvements.

Table 9: Times before and after improvements

| Time | Before improvement | After improvement | Variance |
|---|---|---|---|
| **VA (s)** | 3940.14 | 3940.14 | 0 |
| **NNVA (s)** | 414.27 | 414.27 | 0 |
| **NVA (s)** | 620.09 | 0 | 620.09 |
| **PCE (%)** | 79.21 | 90.49 | -11.280 |
| **MLT (s)** | 4974.496 | 4354.41 | 620.086 |

### *3.6.2. Improvements to the 3R strategy*

The improvements to the 3R strategy (reuse, reduce, and recycle) aimed to improve the strategy that the company had implemented. These were done so that the company could be more efficient in using its waste, scrap production, and resources. The 3R Strategy consists of reuse, reduce, and recycle. 'Reuse' is an activity to reuse an item that is no longer used, such as reusing scrap from the rest of the production. 'Reduce' is an activity to reduce the use of resources such as materials and energy. 'Recycling' is an activity to process the remaining production results to be used as new products, and is done when reuse and reduction cannot be done [23]. Table 10 shows the activities that the company could carry out to improve the existing 3R Strategy.

Table 10: 3R strategy improvements

| Activities | Description |
|---|---|
| **Reuse** | Using scrap from pressing as a new product, such as a putty knife |
| **Reduce** | Reducing product defects and rework by applying SOPs in carrying out the production process to reduce energy use |
| | Reducing the use of Styrofoam for packaging, and replacing it with bio-foam packaging |
| **Recycle** | Processing wastewater with a water treatment plant so that it can be reused for production activities and watering plants |

### *3.6.3. Future sustainable value stream mapping*

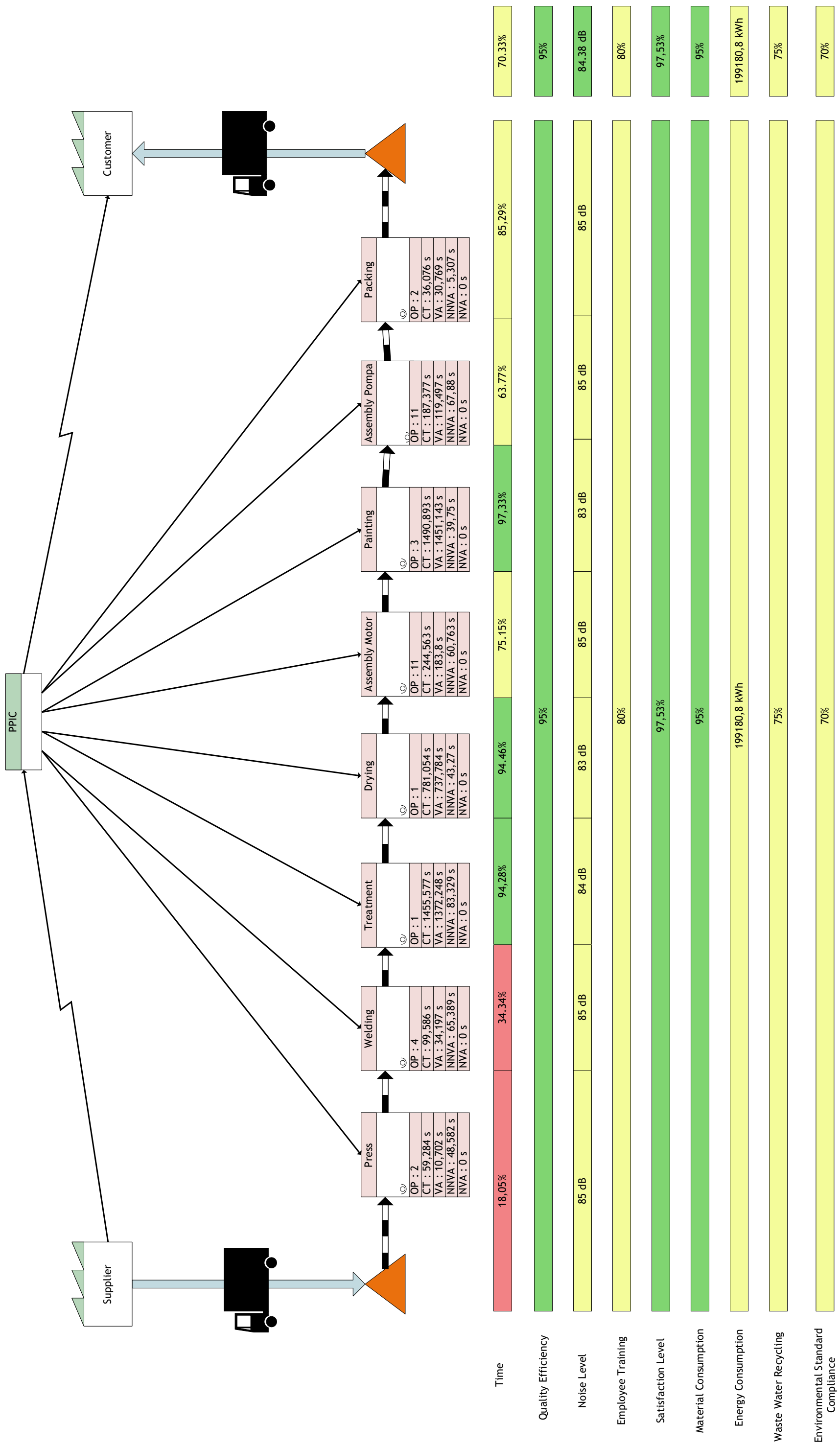



**Figure 3: Future sustainable value stream mapping**

The indicators for future SVSM underwent changes in the performance metrics after the researchers were given suggestions on time, quality efficiency, noise level, employee training, material consumption, and wastewater recycling. The time indicator increased to 70.33% in the economic pillar, and the quality efficiency indicator increased to 95%. The noise level indicator decreased to 84.38 dB in the social pillar, and employee training increased to 80%. In the environmental pillar, the material consumption indicator increased to 95%, and wastewater recycling increased to 75%.

### *3.6.4. Sustainability index*

Improvements were made to reduce waste and the percentage of the SI, which would increase the company's production efficiency. Table 8 shows the results of calculating the SI after the improvements. The value of the SI changed after improvements, decreasing in each pillar. By providing suggestions for the indicators of time, quality of efficiency, noise levels, employee training, material consumption, energy consumption, and wastewater recycling, the current value on performance metrics had improved, affecting the final value of the company's sustainability. The economic pillar changed from 155% to 117%; the social pillar changed from 170% to 134%; and the environmental pillar changed from 265% to 113%. The value of the company's SI decreased from 183% to 118%, which showed that the steps that the company had to take to achieve sustainability were getting smaller. Deviations from sustainability were also getting smaller. This shows that, by implementing improvements, the value of the SI would be better; such suggestions can help companies to optimise their production processes and to minimise waste and pollution, increase resource efficiency, and reduce energy use. Table 11 shows the SIs after the improvements had been implemented. Table 12 compares the SI values before and after the improvements.

**Table 11: Sustainability index after improvements**

| Aspects | Indicator | Performance measures | Performance metrics | | Value of change | SI | | Vector eigen | Overall SI | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Existing | Target | | | | | | |
| Economic | E1 | Time (%) | 70.33 | 80 | 9.67 | 1.17 | 117% | 0.62 | 1.18 | 118% |
| | E2 | Quality efficiency (%) | 95 | 100 | 5 | | | | | |
| Social | S1 | Noise Level (db) | 85 | 85 | 0 | 1.34 | 134% | 0.14 | | |
| | S2 | Employee training (%) | 80 | 100 | 20 | | | | | |
| | S3 | Satisfaction level (%) | 97.53 | 99 | 1.47 | | | | | |
| Environ-mental | N1 | Material consumption (%) | 95 | 95 | 0 | 1.13 | 113% | 0.24 | | |
| | N2 | Energy consumption (kwh) | 199 180.8 | 189 221.76 | 9 959.04 | | | | | |
| | N3 | Waste water recycling (%) | 75 | 75 | 0 | | | | | |
| | N4 | Environmental standard compliance (%) | 70 | 90 | 20 | | | | | |

**Table 12: Sustainability index before and after improvements**

| Sustainability index | Before improvement | After improvement | Variance |
|---|---|---|---|
| **Economic** | 1.55 | 1.17 | 0.376 |
| **Social** | 1.70 | 1.34 | 0.363 |
| **Environmental** | 2.65 | 1.13 | 1.522 |
| **Overall** | 1.83 | 1.18 | 0.650 |

## 4. CONCLUSION

This research was conducted to design a sustainable company using a sustainable lean manufacturing approach. Based on the research data, there was waste in the form of defects, waiting, and excess processing in the company's production processes. Waste was included in the non-value added aspects, and could be eliminated by providing improvements. The efficiency value of the company with non-value-added activities was still 79.21%; the overall SI before the improvement was 183%. The improvements were proposed to improve the indicator values for time, quality efficiency, noise level, employee training, energy consumption, material consumption, and wastewater recycling. The improvement of each indicator would increase efficiency and reduce the value of deviations in the company's SI. After the improvements, the value of the SIs decreased so that the overall SI was 118%, which showed that the effort required by the company to achieve the level of sustainability was becoming less. With the improvements in the SI values, production efficiency also improved by 11.28%, while the process cycle efficiency value improved to 90.49%, so that the company's production processes became more efficient.

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