Management and Production Engineering Review
Volume 14 • Number 4 • December 2023 • pp. 71–91
DOI: 10.24425/mper.2023.147205

Integration of Overall Equipment Effectiveness and Six Sigma Approach to Minimize Product Defect and Machine Downtime

Filscha NURPRIHATIN[1], Glisina Dwinoor REMBULAN[2], Johanes Fernandes ANDRY[3], Maulidina LUBIS[1], Ivana Tita Bella WIDIWATI[1], Ali VAEZI[4]

[1] *Department of Industrial Engineering, Sampoerna University, Indonesia*
[2] *Department of Management, Universitas Bunda Mulia, Indonesia*
[3] *Department of Information Systems, Universitas Bunda Mulia, Indonesia*
[4] *Goodman School of Business, Brock University, Canada*

Received: 29 July 2023
Accepted: 29 August 2023

Abstract
This study was conducted in a company that produces palm oil-based products such as cooking oil and margarine. The study aimed to encounter defects in packaging pouches. This study integrated the overall equipment effectiveness (OEE) with the six sigma DMAIC method. The OEE was performed to measure the efficiency of the machine. Three factors were measured in OEE: availability, performance, and quality. These factors were calculated and compared to the OEE world-class value. Then, the Multiple Linear Regression was performed using SPSS to determine the correlation between measurement variables toward the OEE value. Lastly, the six sigma method was implemented through the DMAIC approach to find the solution and improve the packaging quality. Supposing the recommendations are implemented, the OEE is expected to increase from 82% to 85%, with availability ratio, performance ratio, and quality ratio at, 99%, 86%, and 99.8%, respectively.

Keywords
Overall equipment effectiveness; Six sigma; Multiple linear regression; DMAIC; Packaging quality.

Introduction

Internationally, investors have seen oil as a common financial asset due to its higher value than other commodities in the future (Liu et al., 2022). Presently, Indonesia is ranked as the first top producer of crude palm oil globally, closely followed by Malaysia (Cheah et al., 2023). Therefore, in Indonesia, the palm oil industry has become one of the issues that has attracted the attention of the global community because of its very rapid development. This rapid development was successful because it strengthened the national private large plantations to synergize the oil palm plantation model between smallholders and corporations known as *Perkebunan Inti Rakyat or Perkebunan Inti dan Petani* (Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI), 2018). Due to improved plantation maintenance, favorable weather, and attractive prices, Indonesian palm oil production is expected to increase significantly in 2021, reaching 49 million tons of crude palm oil (CPO) and 4.65 million tons of palm kernel oil (PKO) (Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI), 2021). These developments allow the company to improve quality for all customers. Any strategic plans should focus on omnichannel customers, demographic changes, increasing urbanization, and technological trends (Andry et al., 2022a). This study focuses on one of Indonesia's leading and integrated public companies in the palm oil industry. The company focuses on palm oil-based products such as cooking oil and margarine. Aside from bulk and industrial oil, derivative products are marketed under various brands well-known in Indonesia for their high quality and significant market share in their respective regions.

Industry 4.0 demand industries to utilize technological improvements to produce rapid evolution and transformation in production flow so that performance can be optimized and cost can be reduced (Mendonça et al., 2022). With the increasingly incisive competition between manufacturers, industries

***Corresponding author**: Filscha Nurprihatin – Department of Industrial Engineering, Sampoerna University, Indonesia, e-mail: filscha.nurprihatin@sampoernauniversity.ac.id*

need to maximize their production performance (Nurprihatin et al., 2020). Despite being a leading and integrated company in Indonesia, this company is still competing with other palm oil production companies. Other palm oil production companies also produce the same product, which can result in increasingly fierce competition. As a result, the company must be able to develop products that could enhance customer satisfaction. The quality of the product or packaging is one of the factors that affect customer satisfaction. In addition to being used as a container or wrapper, the packaging is now designed to look more practical and attractive. It also aims to keep the product's condition from being contaminated with other factors until it reaches the consumer. In addition, the quality of the packaging can impact the company's profit margin.

One of the company's products that requires the best quality packaging is cooking oil. Currently, there are several types of packaging for cooking oil, such as stand pouch packaging, pillow packs, and others. The packaging of cooking oil at the company uses pouch packaging with the principle of a pressurized packaging process. The cooking oil packaging process results are inspected to see whether there is a defect in the cooking oil product from the existing machine production. From the inspection results, defective packaging is often found in the cooking oil pouch during production or before the product is transferred to the warehouse. Firstly, the cooking oil leak is caused by two things: the sealer on the machine or the product pouch. Other cases of defective packaging include body defects, seal defects, no code, and less volume. Defective cooking oil products can cause a loss for the company because they cannot be distributed to consumers.

Therefore, to address the issue of defects in cooking oil packaging pouches, the company can integrate OEE with six sigma. OEE is one of the metrics used to determine a factory's overall performance, and it is used to determine a machine's effectiveness (Nurprihatin et al., 2019). OEE is a method of measuring and determining the value of three factors: availability, performance, and quality (Singh et al., 2018). After that, a multiple linear regression analysis will be applied to understand which variable significantly influences the decrease of OEE value. Multiple linear regression provides magnitude and statistical significance estimates for relationships between variables (Karamazova et al., 2017). In addition, the six sigma method through define, measure, analyze, improve, control (DMAIC) stages is used to find the solution and improvement for packaging quality. The objective of six sigma is to reduce the number of defects in products and processes to 3.4 defects per million opportunities (DPMO), which is the target of the program (equivalent to a quality level of 99.9997 percent) (Girmanová et al., 2017). The integration of the two factors by inserting a recommendation improvement and estimating OEE value in the improvement stage aims to illustrate downtime and defect reduction in the packing process.

In this study, activities of the packaging process for pouch cooking oil products were viewed from the perspective of quality control (QC). A study tried to allocate quality control stations considering work in process, and defect probability (Montororing et al., 2022). Hence, the discussion of this study does not deviate from the objectives determined to overcome issues found in the company. For this paper, it is essential to note that the study is only carried out on defective cooking oil packaging products using pouches and the production process or the results of the packaging machine before the product is transferred to the warehouse. In addition, this study did not reach the cost calculation for defects in pouch-packaged cooking oil products. For cost calculation, the authors suggest further research is implemented to assess the economic aspect of the study.

Literature review

The literature review is conducted to study two topics and combine them to be comprehensive research. Therefore, this literature review covers OEE and six sigma topics, as shown in Table 1. The related works mentioned in Table 1 represent the references to OEE and six sigma used to obtain an overview of the approaches used in this paper. These references were chosen based on the objective function carried out. It has been ensured that all references used have the same objective as this paper.

In determining production system performances, OEE is seen as the most vital KPI for production control (Ginste et al., 2022). OEE is a rewarding the Toyota production system metric used to overcome problem-related defects due to ineffective machine performances. It was introduced as a concept to assess a machine's performance while considering sources of production losses. It is, so far, the most influential metric for saving energy and human resources (Mohammadi et al., 2017; Pekarčíková et al., 2023). A study showed that combining the OEE approach and TPM maintenance attempt could enhance machine effectiveness and minimize time lost due to machine downtime (Nurprihatin et al., 2019). This

Table 1
Literature review of related works

Literature review	OEE indicators	MLR	Maintenance	Define	Measure	Analyze	Improve	Control	Objective function
Nurprihatin et al., 2019	Availability, performance, quality	No	TPM	No	No	No	No	No	Increasing machine effectiveness and maintenance performance
Shahin & Attarpour, 2011	Availability, performance, quality	Yes	TPM	No	No	No	No	No	Making maintenance policy
Chiarini, 2015	Availability, performance, quality	No	No	CTQ, LSS justification chart	Average OEE, Sigma level	Fishbone diagram, chi-square test	SMED	SOP, final report	Improving OEE using the Lean six sigma approach
Febriana & Hasbullah, 2021	No	Yes	No	SIPOC	Process capability	FTA, FMEA	Preventive action	SPC	Improving quality, eliminating waste
Lutfianto & Prabowo, 2022	No	No	No	Objective identification	CTQ, DPMO, Sigma level	Fishbone diagram	FMEA	No	Analyzing sigma value and minimizing defects
Patil & Inamdar, 2014	No	No	No	Problem statement and CTQ	Machine efficiency calculation	Pareto analysis	Recommendations and validation	Control assessment	Improving process (overall efficiency improvement)
This paper	Availability, performance, quality	Yes	TPM	SIPOC	CTQ, DPMO, Sigma level	Fishbone diagram	Recommendations and validation	Control Assess-ment	Minimizing defects, improving quality, increasing machine performance

study of a company with a 71.27% OEE value (lower than the world-class ideal value of 85%) discovered that breakdown losses were the highest contributor to the low OEE value. To overcome machine breakdown, their study also provides mean time to repair (MTTR) and mean time between failures (MTBF) calculations as a part of the total productive maintenance (TPM) activity. A previous study also conducted a study on OEE to construct maintenance policies (Shahin & Attarpour, 2011). multiple linear regression (MLR) was used to investigate the significant correlation between the OEE indicator and MTBF (Shahin & Attarpour, 2011). The MLR is also used in this study. However, it is used to find which factor creates the most significant influence on decreasing the OEE value.

Six sigma is a process improvement method that enhances productivity and efficiency through error reduction (Andry et al., 2022b). It is a systematic problem-solving approach for strategic system improvement that utilizes statistical techniques to reduce customer-defined defect rates and/or improve key output (Allen & Shanmugam, 2019). In six sigma, by implementing the DMAIC approach, organizations can improve their activities, increase equipment availability, and enhance customer satisfaction (Nagi & Altarazi, 2017). A previous study tried to implement net promoter score (NPS) as a tool to improve customer satisfaction (Nurprihatin et al., 2022a). However, this study is focused on how six sigma can be used to increase OEE value. In bridging the study between OEE and six sigma, a study found that six sigma can be used to improve OEE (Chiarini, 2015). It is verified that six sigma can increase the OEE from 40% to 61% in which the company's performances are escalated, especially for the on-time delivery performance (Chiarini, 2015). As in this paper, six sigma is used to minimize the number of defects and increase the company's overall performance. A study that integrated six sigma (DMAIC) and MLR to reduce variation in the tire manufacturing industry was conducted to investigate the correlation between the problem and root causes (Febriana & Hasbullah, 2021). Alongside MLR, this paper utilizes the SIPOC (suppliers, inputs, processes, outputs, customers) diagram used in the define phase. Other studies used critical to quality (CTQ), DPMO, and sigma level for the measure phase, fishbone diagram for the analysis phase, recommendations and validations for the improvement phase, and control assessments for the control phase (Lutfianto & Prabowo, 2022; Patil & Inamdar, 2014). These are the tools implemented for the Six Sigma approach in this paper as well.

Finally, other papers related to OEE and six sigma explain more detailed information about the existing literature. These papers include process digitization using value stream mapping and OEE analysis (Klimecka-Tatar & Ingaldi, 2022), a systematic review of OEE and its integrated framework (Cheah et al., 2020; Corrales et al., 2020) and other pertinent works of six sigma, namely, the LSS implementation among enablers and a critical review of LSS methodology (Patel & Patel, 2021; Raval et al., 2018).

Regarding the research gap, this study could add value and bring a new perspective on how OEE can be integrated with six sigma. Specifically, other researchers can utilize this study to minimize product defects and machine downtime. As a result, industries could create leaner processes and robust production performance to meet demand.

Research methodology

In this study, a quantitative research method was applied to collect data. In general, quantitative studies entail systematically collecting data on a phenomenon, utilizing standardized metrics and statistical analysis (Ahmad et al., 2019). Based on the type, this study is classified as descriptive research. A descriptive approach does not include treatment, manipulation, or alteration of the independent variable. Instead, it depicts the state of the condition (Priscylio et al., 2019). In descriptive research, the aim is to conduct a study that answers an existing problem in a systematic and factual manner, using current data as a foundation.

Figure 1 shows the research methodology for this study. The authors conducted a preliminary study to start the research and identify issues found in the company. From these processes, the authors determine the objective of the research to overcome the problems. Next, a literature study was carried out to obtain references related to the topic addressed in this research. The literature review was also conducted to determine the most suitable approach that can be implemented by the authors to surmount the discovered issues.

Next, the authors collect the data through interviews and documentation. The interview was conducted with the filling plant supervisor regarding the cooking oil packaging process, and the researcher learned about the machines used to produce cooking oil in the filling plant. The secondary data refers to information that has been provided by the company in the past on machine/equipment maintenance and product quality. The historical data is collected on machines and product problems from total production for 4 months, from April 2021 to July 2021.

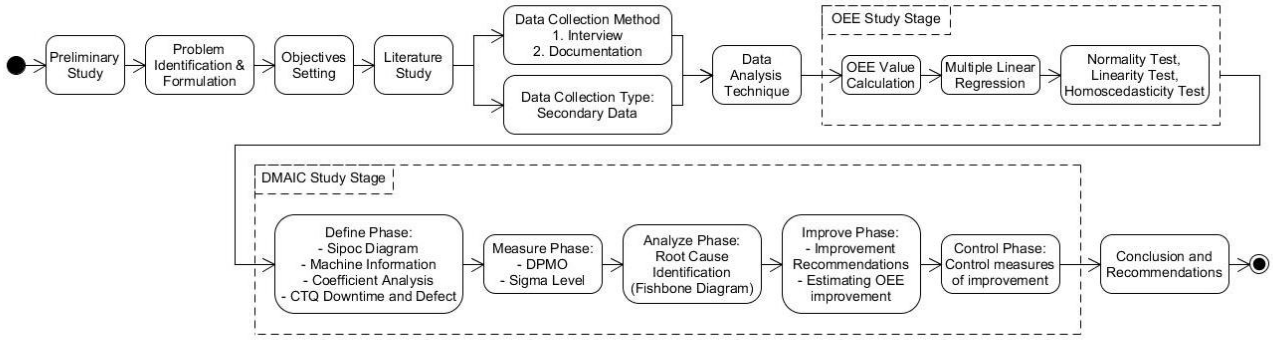

Fig. 1. Research methodology. Source: Authors' own conception

The data collected during the data-collecting process is subsequently processed and calculated in compliance with applicable theories. The data processing method used in this study was OEE, and the six sigma DMAIC approach should be integrated. OEE is a technique for quantifying and valuing three variables: availability, performance, and quality. Following that, a multiple linear regression analysis will be performed to determine which variables significantly affect the decrease in OEE value. Additionally, the six sigma method identifies and improves package quality through DMAIC stages.

The OEE calculation measures the company's performance and machine effectiveness in the first stage. The availability of machines or equipment is determined by comparing the operation and loading times of a machine or equipment. The equipment's performance efficiency (P) is calculated as the proportion of its actual operating speed to its optimum operating speed based on its design capacity. The quality rate (Q) is determined by the number of defective products associated with the equipment, which is then converted to time by deciding how much time the equipment is wasted in producing the defective product.

Then, the DMAIC study is conducted starting from the define phase, continued with the measure, analyze, improve, and control phase in order. This stage will achieve a more in-depth study of the data processing findings based on the outcomes of the previous step. The purpose of analyzing the data in this study is to identify the effectiveness of the usage of machines or production equipment and to improve the quality of the cooking oil packaging production process to reduce the number of defects and machine downtime during the production process. Lastly, the authors conclude the study based on research findings that are consistent with the research objectives. As well as providing valuable suggestions for the company's progress and further research.

Result and discussion

In this part, the OEE calculation and six sigma methodology are performed. As explained in Figure 1, the OEE study stage will include the multiple linear regression (MLR) analysis, which will be done using SPSS. With MLR, the correlation between measurement variables and OEE value is identified. Lastly, the DMAIC approach increases process performance and minimizes defects.

Overall Equipment Effectiveness (OEE) calculation

Before calculating the OEE value, measuring the variables used in the computation is necessary. The variables include loading time, operation time, availability ratio, and performance ratio. Loading time is calculated by subtracting machine available time and anticipated downtime. The operation time is calculated by subtracting the loading time and the downtime. The availability ratio is a ratio that describes the utilization of the time available for the operation of the Thimonnier 2 machine. The availability of machines or equipment is determined by comparing the time that the machine can operate and the loading time of the machine or equipment (Chikwendu et al., 2020). Lastly, the equipment's performance efficiency (P) is calculated as the proportion of its actual operating speed to its optimum operating speed based on its design capacity (Nurcahyo et al., 2018). Table 2 shows the calculation example for all measurement variables for the Thimonnier 2 machine on April 13. The result is shown in Table 3 for the rest of the calculation.

The quality ratio measures an equipment's capacity to produce products that meet specified requirements. To calculate the quality ratio, the total products that are compliant with the quality standard are compared

Table 2
Loading time, operation time, availability ratio, and performance ratio calculation

Measurement	Known variable	Calculation
Loading Time (LT)	Available Time (AT) = 24 hour Planned downtime (PD) = 16.45 hour	Loading Time = Available Time – Planned Downtime Loading Time = (24 − 12.45) hour = 7.55 hour
Operation Time (OT)	Loading Time = 7.55 hour Downtime (D) = 0.8 hour	Operating Time = Loading Time – Downtime Operating Time = (7.55 − 0.8) hour = 6.75 hour
Availability Ratio (AR)	Operating Time = 7.47 hour Loading Time = 7.55	Availability ratio (A) = Operating Time / Loading Time ×100% Availability ratio (A) = 6.75 hour / 7.55 hour ×100% Availability ratio (A) = 89%
Performance Ratio (PR)	Ideal cycle time = 0.00050 hour Total output = 13542 pouches Operation time = 6.75 hour	Performance ratio (P) = (Theoretical Cycle Time × Processes Amount) / (Operating Time) ×100% Performance ratio (P) = (0.00050 × 13542)/6.75 × 100% = 100%

Source: Authors' own calculation

Table 3
Loading time, operation time, availability ratio, and performance ratio result

Month / Date		AT (Hour)	PD (Hour)	D (Hour)	LT (Hour)	OT (Hour)	AR (%)	PR (%)
April 2021	13	24	16.45	0.8	7.55	6.75	89	100
	15	24	8.95	1.51	15.05	13.54	90	93
	16	24	15.83	0.86	8.17	7.31	89	99
	19	24	17.25	0.35	6.75	6.4	95	99
	20	24	17.15	3.83	6.85	3.02	44	99
	23	24	12.8	3.36	11.2	7.84	70	99
	27	24	16	2.17	8	5.83	73	99
	29	24	8	0.67	16	15.33	96	71
May 2021	3	24	20.77	1	3.23	2.23	69	100
	4	24	11	1.24	13	11.76	90	97
	8	24	19	0.45	5	4.55	91	97
	10	24	20.2	0.53	3.8	3.27	86	98
	17	24	10.47	0.83	13.53	12.7	94	98
	25	24	18.27	1.02	5.73	4.71	82	98
	27	24	8	1.91	16	14.09	88	98
	28	24	8	0.83	16	15.17	95	97
	31	24	8	0.17	16	15.83	99	97
June 2021	2	24	8	0.53	16	15.47	97	98
	3	24	18.82	0.33	5.18	4.85	94	96
	7	24	21.23	0.33	2.77	2.44	88	94
	11	24	9.55	0.2	14.45	14.25	99	96
	14	24	22.73	0.3	1.27	0.97	76	100
	17	24	14.08	0.37	9.92	9.55	96	97
	26	24	14.25	0.17	9.75	9.58	98	97
July 2021	14	24	20.77	1.07	3.23	2.16	67	98
	15	24	16.02	2	7.98	5.98	75	92
	16	24	12	1.65	12	10.35	86	98
	30	24	16	1	8	7	88	97
						Average	86	97.1

Source: Authors' own calculation

to the total products made. The calculation of the Quality Ratio for each date can be seen in Table 4, while the calculation example for Quality Ratio (Q) is elaborated as follows:

Good product = 13449 units

Total output = 13524 units

$$\text{Quality ratio}(Q) = (\text{Processed Amount} - \text{Defect Amount})/(\text{Processed Amount}) \times 100\% \quad (1)$$

$$\text{Quality ratio}(Q) = (\text{Good Product})/(\text{Processed Amount}) \times 100\% = 13449/13524 \times 100\% = 99.4\%$$

Table 4
Quality ratio result

Month	Date	Good product	Defect	Total product	Quality ratio (%)
April	13-Apr-21	13449	75	13524	99.4
	15-Apr-21	25037	97	25134	99.6
	16-Apr-21	4136	300	14436	97.9
	19-Apr-21	12571	101	12672	99.2
	20-Apr-21	5937	51	5988	99.1
	23-Apr-21	15257	235	15492	98.5
	27-Apr-21	11453	103	11556	99.1
	29-Apr-21	21607	305	21912	98.6
May	3-May-21	3668	800	4468	82.1
	4-May-21	22704	204	22908	99.1
	8-May-21	8722	100	8822	98.9
	10-May-21	6336	99	6435	98.5
	17-May-21	24576	379	24955	98.5
	25-May-21	9120	94	9214	99.0
	27-May-21	27288	377	27665	98.6
	28-May-21	29340	284	29624	99.0
	31-May-21	30600	194	30794	99.4
June	2-Jun-21	30140	136	30276	99.6
	3-Jun-21	9324	48	9372	99.5
	7-Jun-21	4423	149	4572	96.7
	11-Jun-21	27376	164	27540	99.4
	14-Jun-21	1925	18	1943	99.1
	17-Jun-21	18488	124	18612	99.3
	26-Jun-21	18481	131	18612	99.3
July	14-Jul-21	4200	39	4239	99.1
	15-Jul-21	10920	91	11011	99.2
	16-Jul-21	19992	238	20230	98.8
	30-Jul-21	13524	104	13628	99.2
				Average	98.3

Source: Authors' own calculation

OEE is one of the metrics that can be used to determine a factory's overall performance, and it is used to determine a machine's effectiveness (Nurprihatin et al., 2019). OEE value is obtained by multiplying 3 main ratios: availability, performance rate, and quality ratio. Furthermore, the calculation of the OEE value for each date can be seen in Table 5. The re-

Table 5
Overall equipment effectiveness result

Month	Date	Availability (%)	Performance (%)	Quality (%)	OEE (%)
April	13-Apr-21	89	100	99.4	89
	15-Apr-21	90	93	99.6	83
	16-Apr-21	89	99	97.9	86
	19-Apr-21	95	99	99.2	93
	20-Apr-21	44	99	99.1	43
	23-Apr-21	70	99	98.5	68
	27-Apr-21	73	99	99.1	71
	29-Apr-21	96	71	98.6	67
May	3-May-21	69	100	82.1	57
	4-May-21	90	97	99.1	87
	8-May-21	91	97	98.9	87
	10-May-21	86	98	98.5	83
	17-May-21	94	98	98.5	91
	25-May-21	82	98	99.0	79
	27-May-21	88	98	98.6	85
	28-May-21	95	97	99.0	92
	31-May-21	99	97	99.4	95
June	2-Jun-21	97	98	99.6	94
	3-Jun-21	94	96	99.5	90
	7-Jun-21	88	94	96.7	80
	11-Jun-21	99	96	99.4	95
	14-Jun-21	76	100	99.1	76
	17-Jun-21	96	97	99.3	93
	26-Jun-21	98	97	99.3	95
July	14-Jul-21	67	98	99.1	65
	15-Jul-21	75	92	99.2	68
	16-Jul-21	86	98	98.8	83
	30-Jul-21	88	97	99.2	84
	Average	86	97.1	98.3	82

Source: Authors' own calculation

sult from Table 5 is compared to the OEE value of the world-class standard, as shown in Table 6.

Table 6
OEE World Class Standard

OEE factor	World class
Availability	> 90.0%
Performance rate	> 95.0%
Quality rate	> 99.9%
OEE	> 85.0%

Source: Gallesi-Torres et al., 2020

The comparison is virtualized using a bar chart in Figure 2. From this comparison, it can be concluded that the Thimonnier 2 machine indicates ineffectiveness in its operation. On the chart, it can be observed that the OEE value does not meet the world-class standard. Thus, it must determine the cause of Thimonnier 2 machine ineffectiveness.

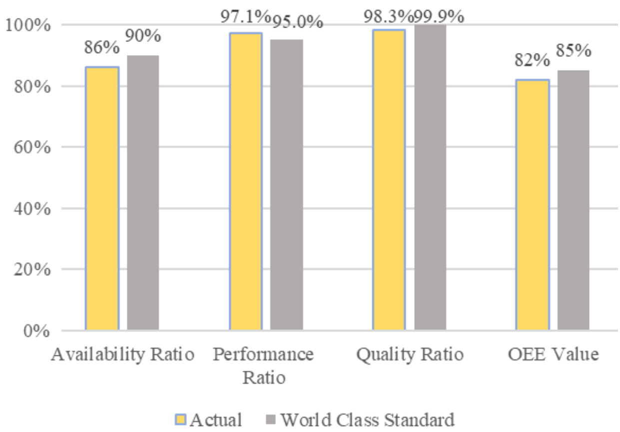

Fig. 2. OEE Value of Actual vs World Class Standard
Source: Authors' own calculation

Determining the cause of machine ineffectiveness using multiple linear regression

A previous study chose the focus on either availability, performance, or quality rate using regression analysis (Nurprihatin et al., 2023). Processing data developed the multiple regression equation used in this study from various measurement variables. The following are the measuring variables that are used:

X_1 – Available Time;
X_2 – Planned Downtime;
X_3 – Downtime;
X_4 – Total Output;
X_5 – Cycle Time;
X_6 – Defect;
Y – OEE.

According to Table 7, the machine planned downtime variable has a correlation value of −0.374, indicating that it has a negative effect on OEE. While the variables' available time and cycle time have a correlation value of 0, this variable has no significant impact. The downtime variable has a correlation value of −0.692, negatively affecting OEE. On the contrary, the total output variable has a correlation of 0.562, indicating that it positively affects OEE. The defect variable has a correlation value of −0.150, indicating that it harms the OEE. Out of the six variables that are considered to influence the achievement of the OEE value, only four independent variables affect the accomplishment of the OEE value, namely planned downtime (X_2), downtime (X_3), total output (X_4), and defects (X_6). Variables available time (X_1) and cycle time (X_5) have no significant effect on the model, so they are excluded from the model.

Test requirement on multiple linear regression

The requirement test for multiple linear regression, also known as the classical assumption test, is performed on the data in testing the hypothesis using parametric statistics, especially in using multiple linear regression. The requirement test for multiple linear regression, or the classical assumption test, is performed on the data. The requirements to be tested include normality, linearity, and homoscedasticity tests.

The normal distribution is represented by a straight diagonal line. According to the normality assumption, the distribution of the dependent variable for each value of the independent variable is normal for each value of the independent variable (Nayebi, 2020). The linearity test aims to determine whether or not two variables have a significant linear relationship. In the homoscedasticity test, the term "homoscedasticity" refers to the assumption that the dependent variable or variables will show the same amount of variation across all possible combinations of the predictor variable(s) (Klemelä, 2018).

The normality test in Figure 3 aims to determine whether a variable is normally distributed. Normal distributions include those in which the line representing the actual data distribution closely follows the diagonal. From the normal probability plot, it can be observed that the actual data distribution closely follows the diagonal so that the data used in the study is normal. Generally, the linearity test in Figure 4 aims to determine whether two variables have a significant linear relationship. Scatterplots of the standardized

Table 7
Correlation analysis result from SPSS

Correlations								
		OEE	Available time	Planned downtime	Downtime	Cycle time	Total output	Defect
Pearson correlation	OEE	1.000	.	–0.374	–0.692	.	0.562	–0.150
	Available time	.	1.000	.	.	.	.	.
	Planned downtime	–0.374	.	1.000	–0.068	.	–0.970	–0.216
	Downtime	–0.692	.	–0.068	1.000	.	–0.115	0.031
	Cycle time	.	.	.	.	1.000	.	.
	Total output	0.562	.	–0.970	–0.115	.	1.000	0.199
	Defect	–0.150	.	–0.216	0.031	.	0.199	1.000
Sig. (1-tailed)	OEE	.	0.000	0.025	0.000	0.000	0.001	0.223
	Available time	0.000	.	0.000	0.000	0.000	0.000	0.000
	Planned downtime	0.025	0.000	.	0.365	0.000	0.000	0.134
	Downtime	0.000	0.000	0.365	.	0.000	0.279	0.438
	Cycle time	0.000	0.000	0.000	0.000	.	0.000	0.000
	Total output	0.001	0.000	0.000	0.279	0.000	.	0.156
	Defect	0.223	0.000	0.134	0.438	0.000	0.156	.
N	OEE	28	28	28	28	28	28	28
	Available time	28	28	28	28	28	28	28
	Planned downtime	28	28	28	28	28	28	28
	Downtime	28	28	28	28	28	28	28
	Cycle time	28	28	28	28	28	28	28
	Total output	28	28	28	28	28	28	28
	Defect	28	28	28	28	28	28	28

Source: Authors' own calculation

residual and predicted value of the dependent variable also evaluate linearity. Based on the scatter plot, it can be explained that there is no significant difference in variance because the plot points above are scattered or do not show a pattern. Therefore, it can be concluded that the regression line is linear. This study examines the residuals (scatter plot), which shows no pattern.

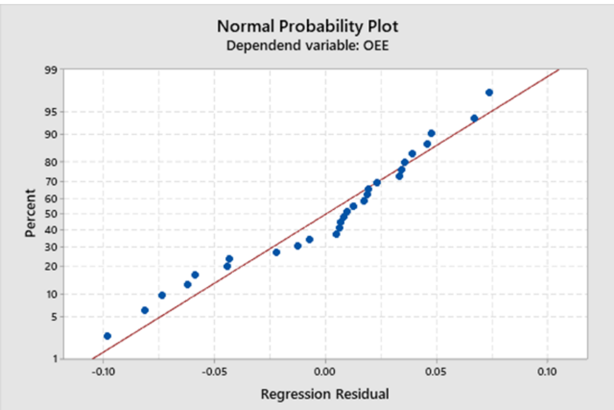

Fig. 3. Normality test. Source: Authors' own calculation

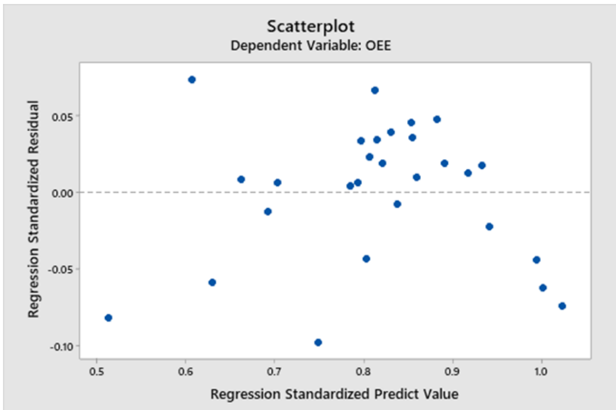

Fig. 4. Linearity test. Source: Authors' own calculation

DMAIC analysis

The define, measure, analyze, improve, and control (DMAIC) method is one of Six Sigma's distinctive methods for process and quality improvement (Girmanová et al., 2017). The SIPOC diagram is initially performed in the define phase, and machine specification is elaborated. Next, the coefficient analysis is performed to analyze the significant influence on the decreasing OEE value. Then, the CTQ is for downtime, and defects are defined. In the measure phase, the DPMO is calculated and converted to obtain the sigma level. This sigma level is then compared to the ideal sigma value. The root cause analysis is performed through a fishbone diagram in the analyze phase. Each of these root causes is analyzed to determine the most effective methods that can be used to minimize problems. These methods are elaborated in the Improve phase. In this phase, recommendations for improvement are given to resolve issues that have arisen. Lastly, the recommendations proposed and implemented in the control phase are monitored to ensure their optimality.

Define

The SIPOC diagram and the Thimonnier 2 machine are elaborated at the define phase. In addition, coefficients analysis is used to identify major influences on the decrease in OEE value that are also described at this stage. Table 8 shows the SIPOC diagram for the packaged cooking oil.

a. Supplier and input – A supplier is a unit that acts as a supplier of goods and is in charge of production activities at a filling and texturing plant. Input is a product received from suppliers or other departments, such as pouches, cartons, cardboard boxes, and cooking oil from the daily tank. Product errors from suppliers that impact product defects in this plant still exist, such as leaky pouches and defective cartons from suppliers.
b. Process – The process consisted of the oil transferring, feeding pouch, open pouch, blowing pouch, filling 1, filling 2, cartooning, sealing, and coding.
c. Output – The output of the production process is packaged edible oil of various sizes, such as 900 ml, 1L, and 2L, ready to be marketed to consumers. However, before being distributed to consumers, the finished good is placed in the finished good warehouse.

Thimonnier THD800 2 machine is an oil packaging production machine that performs filling and coding. This machine has a 360 × 0390 × 250 mm dimension and is equipped with 400 V and 50/60 Hz, 8 KWh power and frequency, respectively. With this power, the machine can produce 2000 pouches per hour. Figure 5 shows the manual instruction for Thimonnier THD800 2 machine.

Identifying the relationship between two or more variables is a common task in engineering. Regression analysis is one of the statistical tools that has long piqued the interest of scientists working in this field (Khademi et al., 2017). One of the regression analyses is multiple linear regression, a technique that can be used to analyze data collected in causal-comparative, correlational, or experimental research. Multiple linear regression provides magnitude and statistical significance estimates for relationships between variables (Karamazova et al., 2017).

From Table 9, only four independent variables affect the achievement of the OEE value, namely planned downtime (X_2), downtime (X_3), total output (X_4), and defects (X_6). Table 10 indicates the regression equation is $Y = -0.505 + 0.055X_2 - 0.036X_3 + 0.000037X_4 - 0.000172X_6$. According to the multiple

Table 8
SIPOC diagram

Supplier	Input	Process	Output	Customer
Daily Tank Supplier Pouch Supplier Cartoon and Cardboard box	Cooking Oil Pouch Cartoon and Cardboard box	Oil Transferring Feeding Pouch Open Pouch Blowing Pouch Filling 1 Filling 2 Cartooning Sealing Coding	Packaged cooking oil IL or 2L	Finished Goods Warehouse

Source: Authors' own calculation

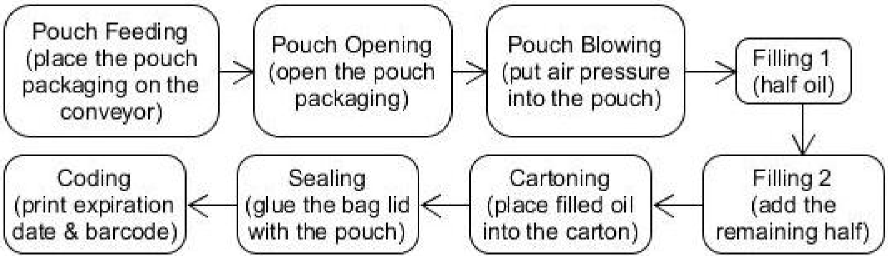

Fig. 5. Thimonnier 2 Machine Manual Instruction. Source: Authors' own conception

Table 9
Coefficient Analysis Result Using SPSS

Coefficients[a]											
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			0-order	Partial	Part	Tolerance	VIF
1	(Constant)	–0.505	0.294		–1.715	0.100					
	Planned downtime	0.055	0.012	2.022	4.512	0.000	–0.374	0.685	0.330	0.027	37.655
	Downtime	–0.036	0.015	–0.255	–2.324	0.029	–0.692	–0.426	–0.170	0.443	2.259
	Total output	3.663E-5	0.000	2.535	5.645	0.000	0.562	0.762	0.412	0.026	37.800
	Defect	0.000	0.000	–0.208	–2.775	0.011	–0.150	–0.501	–0.203	0.950	1.052

Dependent Variable: OEE

Source: Authors' own calculation

Table 10
Failure frequency of component machine

No.	Component Machine	Failure Frequency
1	Gripper	12
2	Opening Bag	10
3	Dosing Pump	6
4	Loading bag	6
5	Block Coding	5
6	Air Hose	5
7	Conveyor Pouch	3
8	Solenoid Air	2
9	Block Sealing	1

Source: Authors' own calculation

linear regression equation, the OEE value achieved due to data processing will increase or decrease in response to a change in the value of one or more variables that affect it. The Y value represents the probability of achieving the OEE value in the future when four independent variables are considered, namely planned downtime (X_2), downtime (X_3), total output (X_4), and defects (X_6). If no variables affect the new OEE value's attainment, the OEE value is -50.5% or -0.505. Negative constants are insignificant and can be ignored if the regression model meets the assumptions. Additionally, this negative constant is unnecessary if the slope value is greater than zero.

The value of the constant will change along with changes in the value of the variables that affect it. The coefficient on the (X_2) variable shows that every increase in machine planned downtime time increases the OEE value of 0.055. Operation time decreases with the same amount of output produced. It will increase the value of the performance ratio so that the OEE value also increases when the other independent variables are constant. The coefficient on the (X_3) variable shows that every hourly increase in downtime decreases the OEE value of 0.036 when the other independent variables are considered constant. The coefficient on the (X_4) variable shows that every increase in total output decreases the OEE value of

0.000037. The coefficient on the (X_6) variable shows that each increase in the defect results in a decrease in the OEE value of 0.000172 when the other independent variables are constant.

Furthermore, conduct a t-test, comparing the value in the significance column to the critical limit value of 0.05. If the signification column value is less than 0.05, H_0 is rejected, indicating that the variable significantly affects the value of OEE. As a result, planned downtime, downtime, total output, and the defect significantly affect OEE. Hence, it can be concluded that downtime and defects have a significant effect on the decreasing value of OEE. As a result, the downtime and defect variables negatively affect the declining value of OEE in the multiple linear regression test, where an increasing value of downtime and defect results in a decrease in the value of OEE. The downtime and defect variables are included in two of the three factors used to calculate the OEE value, i.e., the availability and quality ratios.

Table 10 shows the names of components that failed and the number of failures from April 2021 to July 2021. Figure 6 shows the pareto chart of the failure frequency shown in Table 11. The pareto chart approach conformed to the 80/20 rule, where 80% of activities are caused by 20% of the variables. These six areas contribute approx. 80% less than the total downtime area on the Thimonnier 2 machine. Therefore, this study focuses on these six areas.

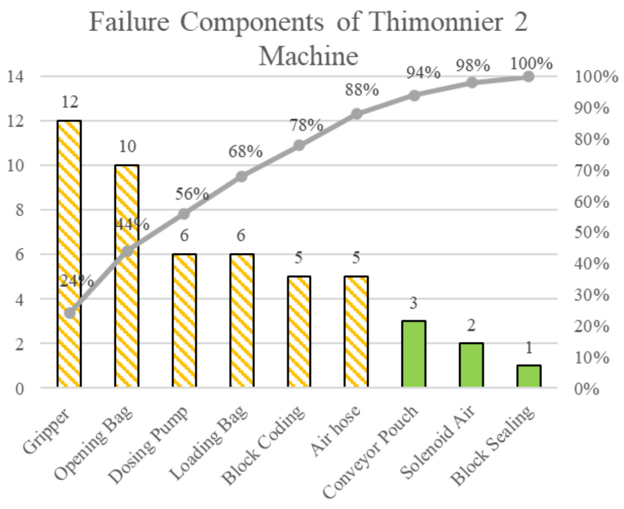

Fig. 6. The Result of CTQ Downtime
Source: Authors' own calculation

Table 11 and Figure 7 show the defect frequency of cooking oil packaging in filling and packaging. Based on the Pareto chart, the most critical defect, with approximately 80% value, is the seal defect, with a percentage of 56%, followed by the body defects having a percentage of 22%. Therefore, this study will focus on these two defective areas.

Table 11
Amount defect of production

Type of Defect	Amount Defect	Defect (%)
Seal Defect	2555	56
Body Defect	1012	22
Less Content Oil	676	15
No Code	192	4
Defective pouch from supplier	97	2

Source: Authors' own calculation

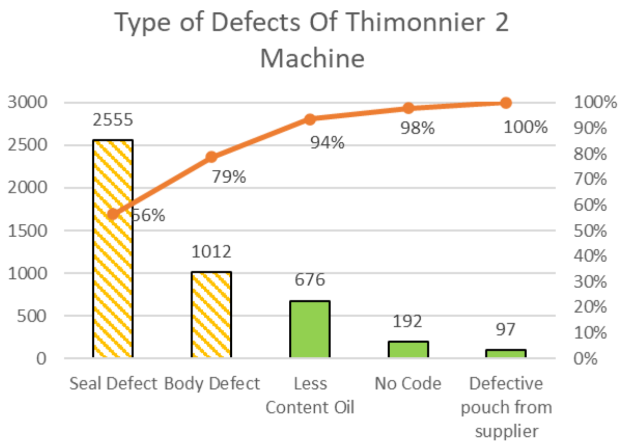

Fig. 7. The Result of CTQ Defect
Source: Authors' own calculation

Measure

DPMO is calculated to determine the current sigma level of the filling plant process. Table 12 shows the level of DPMO and sigma level values from April 2021 to July 2021. The following is the example for calculating defects per million opportunities on April 13, 2021.

$$\begin{aligned}\text{DPMO} &= (\text{Number of Defects} \times 1000000)\\ &\quad /(\text{Number of Possibility} \times \text{Number of Units})\\ \text{DPMO} &= (75 \times 1000000)/(5 \times 13524) = 1109\end{aligned} \tag{2}$$

From Table 13, the DPMO of the company is 2262, which equals to a 4.3 sigma value. The DPMO and sigma values presented above indicate the results of DPMO and sigma with an average of four months

Table 12
DPMO and sigma level calculation result

Date	Total Production	Total Defects	CTQ	DPMO	Sigma Level
13-Apr-21	13524	75	5	1109	4.6
15-Apr-21	25134	97	5	772	4.7
16-Apr-21	14436	300	5	4156	4.1
19-Apr-21	12672	101	5	1594	4.4
20-Apr-21	5988	51	5	1703	4.4
23-Apr-21	15492	235	5	3034	4.2
27-Apr-21	11556	103	5	1783	4.4
29-Apr-21	21912	305	5	2784	4.3
3-May-21	4468	800	5	35810	3.3
4-May-21	22908	204	5	1781	4.4
8-May-21	8822	100	5	2267	4.3
10-May-21	6435	99	5	3077	4.2
17-May-21	24955	379	5	3077	4.2
25-May-21	9214	94	5	2040	4.4
27-May-21	27665	377	5	2725	4.3
28-May-21	29624	284	5	1917	4.4
31-May-21	30794	194	5	1260	4.5
2-Jun-21	30276	136	5	898	4.6
3-Jun-21	9372	48	5	1024	4.6
7-Jun-21	4572	149	5	6518	4.0
11-Jun-21	27540	164	5	1191	4.5
14-Jun-21	1943	18	5	1853	4.4
17-Jun-21	18612	124	5	1332	4.5
26-Jun-21	18612	131	5	1408	4.5
14-Jul-21	4239	39	5	1840	4.4
15-Jul-21	11011	91	5	1653	4.4
16-Jul-21	20230	238	5	2353	4.3
30-Jul-21	13628	104	5	1526	4.5
Average	445634	5040	5	2262	4.3

Source: Authors' own calculation

of production of 4-sigma. Based on the achievement standard, the sigma level of 4 equals the average level of the manufacturing industry in the USA (Gaspersz & Fontana, 2018). This sigma value is quite good, but DPMO and sigma values must be continuously improved to reach world-class levels.

Analyze

In the analysis phase, this study created a fishbone or causal diagram, indicating the primary elements affecting efficiency and quality. From the fishbone diagram, this study identifies the causes of downtime for the machine's components and the product defect. Based on the results of the Pareto chart, the causal analysis was conducted on the gripper, opening bag, loading bag, dosing pump, block coding, and air hose of the Thimonnier 2 machine. In addition, the causal analysis was conducted on the product with seal defects and body defects. Table 13 shows the explanation of the cause-and-effect analysis for the six components' downtime, while Table 14 shows the description of the cause-and-effect analysis of the causes for each defect type.

Improve

During this phase, recommendations for improvement are given to resolve problems that have arisen. Table 15 provides recommendations for improving each potential cause factor on the six components of the Thimonnier 2 THD800 machine and seal defect products at the plant for filling and texturing.

Table 16 shows the result of all measurement indicators. Suppose the recommendations are implemented, the company can reduce unexpected breakdowns because all types of maintenance, including part replacement that is conducted before scheduled production, which the operator is to provide the results of the six components machine inspection in the form of a check sheet to the supervisor before starting the production process. It aims to monitor machine component breakdown by increasing the frequency of machine maintenance. Furthermore, the company can shift its policy from periodic to routine maintenance or preventive maintenance to minimize downtime. The availability ratio will increase if the downtime is decreased for all six downtimes. Based on the regression equation, the coefficient on the (X_3) variable shows that every hourly increase in downtime results in a decrease in the OEE value of 0.036. Herewith, the previous availability rate of 86% increased by 13% to 99%, and the previous OEE value of 82% increased to 83.5% after repairs were made. This finding shows that the OEE value is constant after reducing downtime by 4%. However, the availability ratio keeps increasing. All components are assumed to have zero breakdowns because the six parts are recommended for improvement in this study.

For quality rate, the causes of the high number of product defects include the absence of part-checking

Table 13
The explanation of the cause-and-effect diagram of the causes of six components downtime

Six component downtime	Man	Machine	Material	Method
Gripper Downtime	The operator did not carefully check the gripper components.	The gripper component used is failed or replaced, it can occur because the spring condition on the gripper is weak, so the clamp gripper is not strong enough to clamp the pouch.	The components or materials on the gripper are bolts. Therefore, gripper downtime can be caused by material factors if the bolts to tighten the gripper are worn and the gripper fastening bolts are loose.	The operator did not correctly set the gripper, such as the length and width of the gripper, to clamp pouches of various sizes. If the gripper's opening is too narrow, the pouch will not be optimally stretched or opened. In addition, there is no MTTF or MTTR record.
Opening Bag Downtime	The operator is not paying attention to checking the spare part of the loading bag.	The vacuum rubber opening bag is torn, which causes the loading bag to be unable to open the pouch ideally. In addition, the sensor cannot detect the pouch because the pouch does not touch the sensor.	Low-quality and locally made vacuum rubber that is easily torn.	The operator incorrectly set the blower opening pouch. The position of the blower is not in the center. As a result, the pouch does not open properly. In addition, there is no MTTF or MTTR record.
Dosing Pump Downtime	The operator did not carefully check the spare part of the dosing pump.	The sensor shakes because the sensor's bolt is loose. Additionally, the sensor cable is broken.		There is no MTTF and MTTR record.
Loading Bag Downtime	The operator did not carefully check the spare part of the loading bag.	The solenoid of the loading bag is dirty; it makes the vacuum rubber suction less tight. In addition, the loading bag bolts are loose.	The vacuum rubber is easily torn.	The operator incorrectly setting the distance makes the pouch not lift perfectly. In addition, there is no MTTF and MTTR record.
Air Hose Downtime	The operator is not paying attention to checking the air hose.	The air hose is broken because the wind pressure is too big or strong. In addition to the pressure factor, a broken air hose is also caused by scratches.		There is no MTTF and MTTR record.
Block Coding Downtime	The operator is not paying attention to setting block coding.			The operator incorrectly sets the position of block coding. The block coding is not forward, which makes the code blur on the pouch. In addition, there is no MTTF and MTTR record.

Source: Authors' own calculation

Table 14
The explanation of the cause-and-effect diagram of the causes of seal and body defects

Type of Defect	Man	Machine	Material	Method
Seal Defect	The defective seal can occur during the packaging of cooking oils because the operator is not paying attention to the position of the pouch on the conveyer. It causes the pouch seal to tilt. In addition, the operator is less careful to check any oil in the seal, which causes the pouch to stiffen or harden due to excess oil.	Defective seal products can occur due to the right and left conveyor belts moving unequally so that the pouch position is tilted. This problem must get constant assistance from the operator and be readjusted if the machine appears unbalanced. In addition, one of the vacuum loading bags did not clamp appropriately, so the loading bag tilted to lift the pouch from the conveyer. The position of the pouch will be affected by the result of the sealing process.	If the quality of the product's raw materials is low, the product will be unsafe for usage. The pouch is the raw material referred to in this process. The existence of a seal defect and body defect in the product may be caused to the operator's inaccuracy in monitoring the pouch's quality from the supplier. For example, a supplied pouch that is too thin can cause the sealing quality to drop, which causes the products to be defective.	The lack of accuracy when setting sealing can cause seal defects. Mistakes usually occur during sealing are adjusting the distance from the gripper to the clamp. Furthermore, the timing of the sealing process can also cause defects because the longer the pouch is clamped, the more easily it will be failed, and the temperature range set to seal the pouch. If the temperature is too high, the pouch will become rigid, brittle, and fail.
Body Defect	The operator is less careful in setting the gripper, which causes the gripper not to clamp the pouch properly.	Defective body products can occur because the gripper clamps the pouch too tightly.		The operator is incorrectly setting the gripper, such as the length and width of the gripper, to clamp pouches of various sizes.

Source: Authors' own calculation

Table 15
Recommendations for improving potential cause factor on the six components of the Thimonnier 2 THD 800 machine

Loses	Possible Factor	Possible Cause	Recommendation Improvement
Downtime Machine	Man	The operator did not carefully check the gripper components.	The operator is obliged to provide the results of the gripper or machine inspection before starting the production process to the supervisor. For example, giving the results of the gripper inspection in the form of a check sheet to the supervisor 15 minutes before doing production.
		The operator is not paying attention to checking the spare part of the opening bag.	
		The operator did not carefully check the spare part of the dosing pump.	
		The operator did not carefully check the spare part of the loading bag.	

Table 15 continued

Loses	Possible Factor	Possible Cause	Recommendation Improvement
Downtime Machine		The operator is not paying attention to checking the air hose.	
		The operator is not paying attention to setting block coding.	
	Machine	The spring condition on the gripper is weak.	• Increase the frequency of machine maintenance; it aims to monitor machine component failures. Components such as the spring, clamp, and bolts can be maintained. • The company can shift its policy from periodic maintenance to routine maintenance or preventive maintenance.
		The vacuum rubber opening bag is torn and the sensor opening bag cannot detect the pouch due to the loss sensor.	
		The sensor shakes because the sensor's bolt is loose. Additionally, the sensor cable is broken.	
		The solenoid of the loading bag is dirty, and the loading bag bolts are loose	
		The air hose is broken, and a broken air hose is also caused by scratch	
	Material	The bolts to tighten the gripper are worn and the gripper fastening bolts are loose.	• Replace spare parts regularly. • The supervisor supervises operators to ensure spare parts are being used.
		Low-quality locally made vacuum rubber for opening and loading bags.	• Change spare parts supplier.
	Method	The operator did not correctly set the gripper, such as the length and width of the gripper, to clamp pouches of various sizes.	Creating and executing SOPs constantly for employees to set the machine component.
		The operator incorrectly set the blower opening pouch.	
		The operator incorrectly set the distance.	
		The operator incorrectly set the position of block coding.	
		There is no MTTF and MTTR records	Recording historical MTTF and MTTR data for each part of the machine and calculating spare part life.
Defect loses	Man	The operator is not paying attention to the position of the pouch on the conveyer.	• Calculate the percentage of wrong pouch position when on the conveyor. • Supervise operators who are feeding pouches.
		The operator is less careful to set the gripper.	Creating and executing SOPs constantly for employees to set the gripper component.

Table 15 continued

Loses	Possible Factor	Possible Cause	Recommendation Improvement
Defect loses	Machine	(Seal defect) The condition of the right and left conveyor belts are moving unequally.	• Application of the use of sensors to the position of the pouch before being lifted by the gripper. • Increase the frequency of machine maintenance. The company can shift its policy from periodic maintenance to routine maintenance. • Recording historical MTTF and MTTR data for each part of the machine • Creating and executing SOPs constantly for employees to set the gripper component.
		(Seal defect) One of the vacuum loading bags did not clamp properly, so the loading bag tilted to lift the pouch from the conveyer.	
		(Body defect) The gripper is clamping the pouch too tightly.	
	Material	(Seal and Body defect) The quality pouches are thin.	Improved control over the quality of pouches produced by suppliers. The company can replace random checks with a full inspection system
	Method	(Seal defect) the lack of accuracy when setting sealing.	Creating and executing SOPs constantly for employees to setting machine component
		(Body defect) the lack of accuracy when setting the gripper.	

Source: Authors' own calculation

Table 16
The result of all measurement indicators

Measurement Indicators		Before Improvement (hour)	After Improvement (hour)
Availability Ratio Component	Total Loading Time	262.41	262.41
	Total Downtime	29.48	2.84
	Total Operation Time	232.93	259.57
	Availability Ratio	86%	99%
	OEE value	82%	83.5%
Quality Ratio Component	Total Production	445634	448189
	Total Defect	4974	965
	Total Good Product	440571	443126
	Quality Ratio	98.3%	99.8%
	OEE value	82%	83.5%
OEE Component	Availability Ratio	86%	99%
	Performance Ratio	97.1%	86%
	Quality Ratio	98.3%	99.8%
	OEE value	82%	85%

Source: Authors' own calculation

reports, suppliers who do not provide thin pouches, and not carrying out full inspections. Therefore, the recommendations for improvement include the application of preventive maintenance, the application of supplier quality management, and the application of calculating the age of spare parts. In this study, it is assumed that if the filling and texturing plant implements these improvements properly, the company can eliminate defects that occur. The coefficient on the (X_6) variable shows that every hourly increase in defect decreases the OEE value of 0.00127. The creation of zero defects in the type of seal and body defect product causes an increase in the quality rate from 98.3% to 99.8%. Lastly, the company may improve OEE by 3% by implementing improvements, from 82% to 85%, assuming there is no downtime and no defects. This increase in OEE can be achieved if the company correctly executes all repairs. These repairs include ensuring all types of records on the maintenance check sheet are implemented and monitored properly, checking the check sheet is implemented thoroughly and becomes a production culture, and establishing full inspection to check the quality standards of material from the supplier.

Control

This final phase aims to control the process to run according to the initial objective. In this phase, the solution provided in the previous phases will be monitored and standardized to ensure the problem is under control (Trimarjoko et al., 2020). Therefore, the following control measures are required:

1. Routine control for checking machine components in the form of a check sheet shows machine components are often replaced or repaired before production.
2. Frequency control of machine inspections, especially for components of machines that have been in use for a long time, by changing periodic maintenance into preventive maintenance, recording historical MTTF and MTTR data for each part of the machine, and calculating spare part life in report form.
3. Utilization of sensors to determine the position of the pouch before its being lifted by the gripper.
4. Stabilization of SOPs for Thimonnier 2 machine setting component employees.
5. Supervision for operators who are feeding pouches.

Implementing quality management from suppliers that changes random inspections into full inspections to evaluate pouch quality.

Conclusions and recommendations

According to this study's findings, the OEE for the Thimonnier 2 THD800 L machine in the filling and texturing plant from April to July 2021 is 82%, with availability ratio, performance ratio, and quality ratio of 86%, 97.1%, and 98.3%, respectively. The results of linear regression analysis show that the decrease in OEE value on the Thimonnier 2 machine includes breakdown time, setup and adjustment (availability ratio), and defect (quality ratio). According to the pareto chart, the gripper, opening bag, dosing pump, loading bag, air hose, and block coding have the highest failure intensity with a cumulative percentage of 88% and require the most component changes. From this chart, the most critical defect with the most significant percentage value is the seal defect and the body defect, with a percentage of 56% and 22%, respectively. The root causes of these losses include operator negligence in feeding pouches and checking machine components, not checking these six components regularly, and suppliers who do provide thin pouches. The result of calculating DPMO is 2262. The DPMO and sigma values presented above indicate the results of DPMO and sigma with an average of four months of production of 4-sigma.

In increasing the OEE value, the following recommendations for improvement are suggested: using a check sheet to identify machine components that are frequently replaced or repaired prior to the production process, converting periodic maintenance to preventive maintenance, recording historical MTTF and MTTR data for each part of the machine and calculating spare part life in a report, and utilizing sensors to determine the position of the pouch before its lifted by the trough, implementing quality management from suppliers that change random inspections into a full assessment to evaluate pouch quality, and creating and executing of SOPs constantly for employees to setting the component machine. It is estimated that the implementation of improvements will increase OEE to 85%, with an availability ratio of 99%, a performance ratio of 86%, and a quality ratio of 99.8%.

A company must maximize resources to generate qualified products to compete in the market (Nurprihatin et al., 2022b). The implementation of the suggested improvements requires the participation of all company stakeholders. Due to this, its performance requires careful preparation, planning, and supervision and a strong commitment from all internal company parties. Further research should consider OEE calculations performed on the machine Thimonnier 2 and Thimonnier 1. When conducting OEE measurements, it is advisable to use more data; more than one year of data is suggested. In addition, the authors also suggested future research for cost calculation so that the economic aspect of the study can be assessed further. In turn, it could help managers to make decisions and increase long-term profits (Andry et al., 2023).

References

Ahmad, S., Wasim, S., Irfan, S., Gogoi, S., Srivastava, A., & Farheen, Z. (2019). Qualitative v/s. quantitative research- a summarized review. *Journal of Evidence Based Medicine and Healthcare*, 6(43), 2828–2832. DOI: 10.18410/jebmh/2019/587.

Allen, T.T., & Shanmugam, R. (2019). Introduction to engineering statistics and lean six sigma: statistical quality control and design of experiments and systems. *Journal of Statistical Computation and Simulation*, 89(15), 2980–2980. DOI: 10.1080/00949655.2019.1589122.

Andry, J.F., Nurprihatin, F., & Liliana, L. (2022a). Supply chain mapping to prepare golden generation 2045 for future technology infrastructure. E3S Web of Conferences (Vol. 359). DOI: 10.1051/e3sconf/202235905004.

Andry, J.F., Nurprihatin, F., & Liliana, L. (2022b). Supply chain disruptions mitigation plan using six sigma method for sustainable technology infrastructure. *Management and Production Engineering Review*, 13(4), 88–97. DOI: 0.24425/mper.2022.142397.

Andry, J.F., Nurprihatin, F., & Liliana, L. (2023). Developing a decision support system for supply chain component. *Management and Production Engineering Review*, 14(2), 124–133. DOI: 0.24425/mper.2023.146029.

Cheah, C.K., Prakash, J., & Ong, K.S. (2020). Overall equipment effectiveness (OEE): a review and development of an integrated improvement framework. *International Journal of Productivity and Quality Management*, 1(1), 1–26. DOI: 10.1504/IJPQM.2019.10020889.

Chiarini, A. (2015). Improvement of OEE performance using a lean six sigma approach: an Italian manufacturing case study. *International Journal of Productivity and Quality Management*, 16(4), 416–433. DOI: 10.1504/IJPQM.2015.072414.

Chikwendu, O.C., Chima, A.S., & Edith, M.C. (2020). The optimization of overall equipment effectiveness factors in a pharmaceutical company. *Heliyon*, 6(4). DOI: 10.1016/j.heliyon.2020.e03796.

Corrales, L. del C.N., Lambán, M.P., Korner, M.E.H., & Royo, J. (2020). Overall equipment effectiveness: systematic literature review and overview of different approaches. *Applied Sciences*, 10(18), 6469–6489. DOI: 10.3390/app10186469.

Febriana, T.H., & Hasbullah, H. (2021). Analysis and defect improvement using FTA, FMEA, and MLR through DMAIC phase: case study in mixing process tire manufacturing industry. *Journal Européen Des Systèmes Automatisés*, 54(5), 721–731. DOI: 10.18280/jesa.540507.

Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI), (2018, November). *Perkembangan Mutakhir Industri Minyak Sawit Indonesia*. Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI). https://gapki.id/news/3971/perkembangan-mutakhir-industri-minyak-sawit-indonesia.

Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI), (2021). *Refleksi Industri Sawit 2020 dan Prospek 2021*. Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI). https://gapki.id/news/18768/refleksi-industri-sawit-2020-prospek-2021.

Gallesi-Torres, A., Velarde-Cabrera, A., León-Chavarri, C., Raymundo-Ibañez, C., & Dominguez, F. (2020). Maintenance management model under the TPM approach to reduce machine breakdowns in Peruvian giant squid processing smes. IOP Conference Series: Materials Science and Engineering, 796(1). DOI: 10.1088/1757-899x/796/1/012006.

Gaspersz, V., & Fontana, A. F. (2018). *Lean six sigma for manufacturing and service industries waste elimination and continuous cost reduction*. Bogor: Vinchristo Publication.

Ginste, L. Van De, Aghezzaf, E.-H., & Cottyn, J. (2022). The role of equipment flexibility in Overall Equipment Effectiveness (OEE)-driven process improvement. *Procedia CIRP*, 107, 289–294. DOI: 10.1016/j.procir.2022.04.047.

Girmanová, L., Šolc, M., Kliment, J., Divoková, A., & Mikloš, V. (2017). Application of six sigma using DMAIC methodology in the process of product quality control in metallurgical operation. *Acta Technologica Agriculturae*, 20(4), 104–109. DOI: 10.1515/ata-2017-0020.

Karamazova, E., Jusufi Zenku, T., & Trifunov, Z. (2017). Analysing and comparing the final grade in mathematics by Linear Regression using excel and SPSS. *International Journal of Mathematics Trends and Technology*, 52(5), 334–344. DOI: 10.14445/22315373/IJMTT-V52P549.

Khademi, F., Akbari, M., Jamal, S.M., & Nikoo, M. (2017). Multiple linear regression, artificial neural network, and fuzzy logic prediction of 28 days compressive strength of concrete. *Frontiers of Structural and Civil Engineering*, 11(1), 90–99. DOI: 10.1007/s11709-016-0363-9.

Klemelä, J. (2018). Multivariate Data Analysis. In *Nonparametric Finance* (pp. 95–120). DOI: 10.1002/9781119409137.ch4.

Klimecka-Tatar, D., & Ingaldi, M. (2022). Digitization of processes in manufacturing SMEs – value stream mapping and OEE analysis. *Procedia Computer Science*, 200, 660–668. DOI: 10.1016/j.procs.2022.01.264.

Liu, L., Geng, Q., Zhang, Y., & Wang, Y. (2022). Investors' perspective on forecasting crude oil return volatility: where do we stand today? *Journal of Management Science and Engineering*, 7(3), 423–438. DOI: 10.1016/j.jmse.2021.11.001.

Lutfianto, M.A., & Prabowo, R. (2022). Implementation of six sigma methods with failure mode and effect analysis (FMEA) as a tool for quality improvement of newspaper products (case study: PT. ABC Manufacturing – Sidoarjo, East Java – Indonesia). *Journal of Integrated System*, 5(1), 87–98. DOI: 10.28932/jis.v5i1.4615.

Mendonça, P.A., Francisco, R. da P., & Rabelo, D. de S. (2022). OEE approach applied to additive manufacturing systems in distributed manufacturing networks. *Computers & Industrial Engineering*, 171. DOI: 10.1016/j.cie.2022.108359.

Mohammadi, M., Rai, P., & Gupta, S. (2017). Performance evaluation of bucket Based Excavating, Loading and Transport (BELT) equipment – An OEE approach. *Archives of Mining Sciences*, 62(1), 105–120. DOI: 10.1515/amsc-2017-0008.

Montororing, Y.D.R., & Nurprihatin, F. (2021). Model of quality control station allocation with consider work in process, and defect probability of final product. *Journal of Physics: Conference Series*, 1811(1). DOI: 10.1088/1742-6596/1811/1/012013.

Nagi, A., & Altarazi, S. (2017). Integration of value stream map and strategic layout planning into DMAIC approach to improve carpeting process. *Journal of Industrial Engineering and Management*, 10(1), 74–97. DOI: 10.3926/jiem.2040.

Nayebi, H. (2020). *Advanced statistics for testing assumed causal relationships: multiple regression analysis path analysis logistic regression analysis*. Springer Nature. https://books.google.co.id/books/about/Advanced_Statistics_for_Testing_Assumed.html?id=acL3DwAAQBAJ&redir_esc=y#:~:text= This book concentrates on linear regression%2C path analysis, using simple examples without requesting any mathematical knowledge.

Nurcahyo, R., Faisal, & Dachyar, M. (2018). Overall Equipment Effectiveness (OEE) at the laboratory of structure testing. *Proceedings of the International Conference on Industrial Engineering and Operations Management, IEOM 2018*, 1080–1090.

Nurprihatin, F., Angely, M., & Tannady, H. (2019). Total productive maintenance policy to increase effectiveness and maintenance performance using overall equipment effectiveness. *Journal of Applied Research on Industrial Engineering*, 6(3), 184–199. DOI: 10.22105/jarie.2019.199037.1104.

Nurprihatin, F., Ayu, Y.N., Rembulan, G.D., Andry, J.F., & Lestari, T.E. (2023). Minimizing product defects based on labor performance using linear regression and six sigma approach. *Management and Production Engineering Review*, 14(2), 88–98. DOI: 10.24425/mper.2023.146026.

Nurprihatin, F., Jayadi, E.L., & Tannady, H. (2020). Comparing heuristic methods' performance for pure flow shop scheduling under certain and uncertain demand. *Management and Production Engineering Review*, 11(2), 50–61. DOI: 10.24425/mper.2020.133728.

Nurprihatin, F., Mardhatillah, N.R., Young, M.N., Liman, S.D., Redi, A.A.N.P., & Prasetyo, Y.T. (2022a). Integration of Net Promoter Score and DMAIC Approach to Measure Customer Satisfaction in Packaging Industry. *2022 International Conference on Computational Modelling, Simulation and Optimization (ICCMSO)*, 220–225. DOI: 10.1109/ICCMSO58359.2022.00052.

Nurprihatin, F., Rembulan, F.D., & Pratama, Y.D. (2022b). Comparing probabilistic economic order quantity and periodic order quantity model performance under lumpy demand environment. *Management and Production Engineering Review*, 13(4), 16–25. DOI: 10.24425/mper.2022.142391.

Patel, A.S., & Patel, K.M. (2021). Critical review of literature on lean six sigma methodology. *International Journal of Lean Six Sigma*, 12(3), 627–674. DOI: 10.1108/IJLSS-04-2020-0043.

Patil, A.B., & Inamdar, K.H. (2014). Process improvement using DMAIC approach: case study in downtime reduction. *International Journal of Engineering Research & Technology (IJERT)*, 3(3), 1930–1934. DOI: 10.17577/IJERTV3IS031609.

Pekarčíková, M., Trebuna, P., Kliment, M., Trojan, J., Kopec, J., Dic, M., & Kronová, J. (2023). Case study: testing the overall efficiency of equipment in the production process in TX plant simulation software. *Management and Production Engineering Review*, 14(1), 34–42. DOI: 10.24425/mper.2023.145364.

Priscylio, G., Rochintaniawati, D., & Anwar, S. (2019). Needs of integrated science textbook for junior high schoolbased on learning style (descriptive research). *International Conference on Mathematics* *and Science Education of Universitas Pendidikan Indonesia*, 396–401. http://science.conference.upi.edu/proceeding/index.php/ICMScE/article/view/28

Raval, S.J., Kant, R., & Shankar, R. (2018). Lean Six Sigma implementation: modelling the interaction among the enablers. *Production Planning & Control*, 29(12), 1010–1029. DOI: 10.1080/09537287.2018.1495773.

Shahin, A., & Attarpour, M.R. (2011). Developing decision making grid for maintenance policy making based on estimated range of overall equipment effectiveness. *Modern Applied Science*, 5(6), 86–97. DOI: 10.5539/mas.v5n6p86.

Singh, R.K., Clements, E.J., & Sonwaney, V. (2018). Measurement of overall equipment effectiveness to improve operational efficiency. *International Journal of Process Management and Benchmarking*, 8(2), 246–261. DOI: 10.1504/IJPMB.2018.1001026.

Trimarjoko, A., Purba, H.H., & Nindiani, A. (2020). Consistency of dmaic phases implementation on six sigma method in manufacturing and service industry: a literature review. *Management and Production Engineering Review*, 11(4), 34–45. DOI: 10.24425/mper.2020.136118.