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Implementation of Lean Manufacturing Based on A Waste Assessment Model to Reduce Waste in Margarine Packaging Machines

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Abstract
This research is motivated by the existence of waste on margarine packaging machines that have the potential to hinder the smooth production process and cause the occurrence of activities that do not provide added value. The purpose of this study, among others, to analyze the dominance of waste, identify the characteristics and root causes of waste dominant, and formulate corrective actions based lean manufacturing on margarine packaging machines using the waste assessment model (WAM). The results showed that waste waiting is the largest waste with a percentage of 28.90%, followed by defects of 24.34% ,overprocessing of 15.95%, motion of 15.66%, and transportation of 15.14%, so that waste waiting and waste defect are designated as priority waste by mapping activities using process activity mapping there are non-value added activities in waste waiting of 464.74 minutes and waste activity of 872.91 minutes or 50.35% occurred in the bag sealer machine. Furthermore, using fishbone diagrams to find the main cause of the problem and FMEA analysis used to identify critical problems that become the basis for the implementation of lean manufacturing which includes standardization of machine parameters, inspection and maintenance of sealing components, preparation of inspection checklists, determination of parameters and verification of machine functions after adjustment, improvement of operator competence in responding to machine alarms and checking the quality of sealing results.
Keywords: *fmea, lean manufacturing, margarine packaging machine, waste assessment model*

Abstrak
Penelitian ini dilatarbelakangi oleh adanya pemborosan/waste pada mesin pengemasan margarine yang berpotensi menghambat kelancaran proses produksi dan menyebabkan terjadinya aktivitas yang tidak memberikan nilai tambah. Tujuan penelitian ini antara lain untuk menganalisis dominansi waste, mengidentifikasi karakteristik dan akar permasalahan waste dominan, serta merumuskan tindakan perbaikan berbasis lean manufacturing pada mesin pengemasan margarine dengan menggunakan metode waste assessment model (WAM). Hasil penelitian menunjukkan bahwa waste waiting merupakan waste terbesar dengan persentase 28,90%, diikuti defect sebesar 24,34% ,overprocessing sebesar 15,95%, motion sebesar 15,66%, dan transportation sebesar 15,14%, sehingga waste waiting dan waste defect ditetapkan sebagai waste prioritas dengan pemetaan aktivitas yang menggunakan process activity mapping terdapat aktivitas non-value added pada waste waiting sebesar 464,74 menit dan waste defect sebesar 63,88 menit dari total keseluruhan aktifitas sebesar 872,91 menit atau 50,35% terjadi di mesin bag sealer. Selanjutnya menggunakan diagram fishbone untuk menemukan penyebab utama permasalahan serta analisa FMEA yang digunakan untuk mengidentifikasi permasalahan kritis sehingga menjadi dasar penerapan lean manufacturing yang meliputi standardisasi parameter mesin, pemeriksaan dan pemeliharaan komponen sealing, penyusunan checklist pemeriksaan, penetapan parameter serta verifikasi fungsi mesin setelah penyetelan, peningkatan kompetensi operator dalam merespons alarm mesin dan memeriksa kualitas hasil penyegelan.
Kata Kunci: *fmea, lean manufacturing, mesin pengemasan margarin, model penilaian limbah*

1. Introduction

In the world of margarine processing industry, operational efficiency and machine performance are crucial factors to gain an edge over the competition, especially when facing the demands of the global market that wants high quality, cost efficient, and timely delivery. One of the main challenges in this study is the decline in production on margarine packaging machines named pattyn machine line 2. It is shown

that the production produced an average of 7 packs weighing 15 kg per minute, but in reality only produced an average of 5 packs weighing 15 kg per minute.

This pattyn machine plays an important role in the final stages of production but often experience sudden damage, uneven packaging speed which has an impact on the realization of defects in margarine packaging, increasing the amount of downtime and defects. Defects that occur in margarine packaging machines (pattyn) in 2024 with a total of 39900.63 kg . In 2025, the largest defect occurred in February 2025, which was 4200.04 kg while the lowest defect was 2130.03 kg . In 2025, the largest defect occurred in May at 4200.05 kg while the lowest defect in april was 3240.04 kg. In the margarine packaging machine (pattyn) has the largest percentage of defect proportion occurs in 2025 at 1.40% and within two years while in 2024 it has a porposi defect of 1.38%. However, the company wants to minimize the defect as low as possible. In this case, the company has set the threshold for the proportion of defects at 1%.

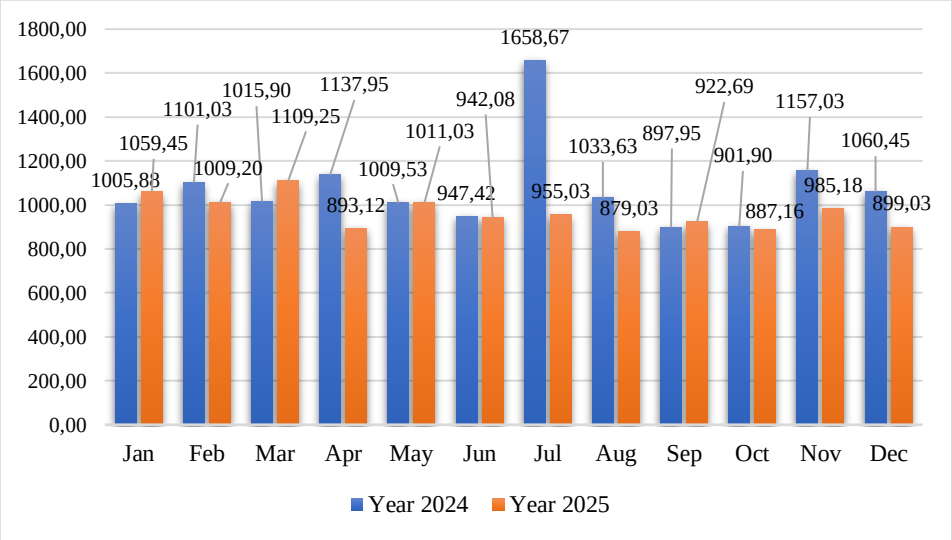


Fig.1: Downtime in margarine packaging machine
Source: Enterprise data (2025)

In figure 1 describes the downtime that occurs in the margarine packaging machine (pattyn) which fluctuates significantly. In 2024, it had the largest downtime in July at 1658.67 minutes while the lowest downtime occurred in September at 897.95 minutes. In 2025, the largest downtime occurred in March at 1109.25 minutes while the smallest downtime occurred in August at 879.03 minutes.

To overcome these problems, a comprehensive approach is needed systematically by eliminating waste from every aspect of the operation. The approach is through the application of lean manufacturing. Based on the previous study as a whole, there are several significant trends. First, a number of studies apply lean through certain tools directly, such as 5S, visual control, SLP, SMED , and quality approaches conducted by Amoretti-Magallanes (2024), Garcia-Garcia (2022) and Cabrera (2020).This method is effective when the main problem is already recognized and the tool is selected in accordance with the nature of the problem[7][10][14]. However, this method does not yet fully offer a structured mechanism for identifying the most conspicuous types of waste when different types of waste appear together[2][3][4]. Second, some studies apply a more inclusive lean approach, which includes lean six sigma, DMAIC conducted by Sasikumar et al. (2023) as well as lean integration with quality or sustainability approaches[1][8].This method has the advantage of presenting a comprehensive framework for improvement, but on the other hand, the analysis can be broader and does not specifically emphasize the determination of waste dominance at the level of one machine[9][11].

Third, research that applies the waste assessment model (WAM) provides a more structured approach to evaluating the relationship and dominance of waste. Research by Hasan and Osman Zahid (2025) shows the application of WAM in manufacturing environments to identify areas of waste that require attention[16]. However, the context of the object focuses on the production of hot coil spring, so there are still opportunities to develop the application of WAM in the context of packaging machinery food industry, especially margarine[12].

Therefore, this study establishes a waste assessment model as an initial diagnostic stage to establish a more systematic basis in determining the direction of improvement. Based on this, there are the following research gaps is collection with the relationship between the results of waste assessment with the analysis

of characteristics and factors that cause waste. The dominant waste management through WAM has not automatically eliminated most of the waste that is still in the field. Therefore, the current study examines the results of WAM by characterizing waste based on location or process stage, activity form, frequency, duration, and relevant indicators using activity mapping process analysis (PAM) and VSM (value stream mapping). After the character is known, the causal factors are analyzed through observation and information from the brain involved in the observation process, then compared using analytical tools such as fishbone diagrams and FMEA (failure mode and effect analysis). Thus, the results of the study are not proven in the study that a waste produces a dominant waste, but also explain why the waste dominates and how the waste is formed in the margarine processing process and how the relevant solutions to reduce the waste.

This suggests that there is a need for research linking the three levels of analysis sequentially. The first level is Assessment, which systematically identifies the dominant waste. The second level is diagnosis, that is, understanding the characteristics and factors that cause the predominant waste in the real activity of the machine. The third level is the formulation of improvements, that is, converting the results of the diagnosis into lean manufacturing-based improvement measures. The purpose of this study, among others, to analyze the dominance of waste, identify the characteristics and root causes of waste dominant, and formulate corrective actions and implement lean manufacturing based on the level of criticality of the problem in the margarine packaging machine.

Novelty of this study lies in the adaptation of the development of lean manufacturing application flow based on WAM that connects the determination of waste dominance with the inherent characterization of margarine packaging machines, through the analysis of process activity mapping (PAM) and VSM (value stream mapping) after which the analysis of the causes of the most critical problems and the formulation of remedial action. The development also distinguishes current research from previous research that directly selected specific lean tools. In this study, remedial action has an empirical basis of the results of WAM and fishbone diagram and FMEA which functioned as a supporting tool for the identification of factors that cause relevant problems occur in margarine packaging machines. This study applies lean manufacturing by using waste assessment model (WAM) to determine the level of waste dominance. The dominant Waste obtained is then analyzed based on the characteristics and causal factors with the help of fishbone diagrams and failure mode and effect analysis (FMEA) which serves as a supporting analysis tool in determining critical problems which then becomes the basis for determining lean improvement action recommendations and lean manufacturing based implementation

Thus, this study is expected to produce proposals and implementation of targeted improvements and provide a measurable picture of the reduction of waste in margarine packaging machines in order to create a highly responsive production system, reliable, and efficient and create an organizational culture that focuses on the elimination of waste, quality improvement, and continuous improvement in margarine processing companies.

2. Material and Methods

This study employed an adapted waste assessment model, beginning with the mapping of the margarine packaging system using value stream mapping (VSM) and process activity mapping (PAM) as the basis for identifying waste and its relevant characteristics in the margarine packaging process, utilizing the Waste relationship matrix (WRM) and the Waste assessment questionnaire (WAQ) to determine the level of waste dominance and analyze root causes using a fishbone diagram based on observations and interviews[5], followed by a failure mode and effect analysis (FMEA). Subseque ntly, the results of these analyses were used as the basis for evaluating and implementing recommended improvement measures grounded in lean manu facturing principles.

Value stream mapping current state

Value stream mapping (VSM) is a tool used to transform processes in order to achieve more efficient production or lean manufacturing. It aims to reduce waste in the manufacturing process. Value stream mapping can be described as a tool that helps companies visualize the entire production process, which encompasses both materials and information[13]. It can be defined as a collection of all value-adding and non-value-adding activities that work together to move a product or group of products using the same resources from raw materials through to the finished product and ultimately to the consumer[6].

Waste assessment model

The waste assessment model (WAM) is a model developed to facilitate the detection and identification of waste, with the aim of eliminating waste. The Waste Assessment Model offers advantages

such as a simplistic matrix that covers a wide range of factors, using a questionnaire to obtain accurate results in identifying the relationship between waste and its causes (Rawabdeh, 2005). Waste can have an impact on other aspects of production. The relationships among different types of waste are highly complex because the impact of each type on the others can be either direct or indirect.

The waste relationship matrix (WRM) was adapted from a framework developed by Rawabdeh (2005). The WRM is used to analyze and measure the relationships between different types of waste. The WRM is a matrix used to analyze measurement criteria. It consists of rows and columns (Rawabdeh, 2005). The waste relationship matrix (WRM) was adapted from a framework developed by Rawabdeh (2005). The WRM is used to analyze and measure the relationships between different types of waste. The WRM is a matrix used to analyze measurement criteria. It consists of rows and columns (Rawabdeh, 2005). Each row indicates the influence of a specific type of waste on the other six types of waste. Meanwhile, each column indicates the types of waste that are influenced by other types of waste.For each relationship, six questions are then asked using the scoring guidelines shown in **Table 1**, which outlines the criteria for waste-related questions.

Table 1. Items Questions for WRM Analysis

Questions	Answer Choices	Score
Does i produce j?	a. Always	= 4
	b. Sometimes	= 2
	c. Rarely	= 0
What is the relationship between i and *j*	a. If i increases, then j increases	= 2
	b. If i increases, then j remains the same	= 1
	c. It depends on the situation	= 0
The effect of i on j	a. Immediately and clearly visible	= 4
	b. Takes time to appear	= 2
	c. Does not appear often	= 0
Eliminating the effect of i on j can be achieved by	a. Engineering methods	= 2
	b. Simple and straightforward	= 1
	c. Instructional solutions	= 0
The effect of i on j primarily influences ...	a. Product quality	= 1
	b. Resource productivity	= 1
	c. Lead time	= 1
	d. Quality and productivity	= 2
	e. Quality and lead time	= 2
	f. Productivity and lead time	= 2
	g. Quality, productivity, and lead time	= 4
To what extent will the impact of i on j increase the lead time?	a. Very high	= 4
	b. Moderate	= 2
	c. Low	= 0

Source: Rawabdeh (2005)

Each answer has a different score, and the total score is derived from the six questions for each waste-to-waste relationship. This total score is converted using a conversion table; the six questions listed above will be asked for each waste-to-waste relationship, resulting in a total of 186 questions (31 relationships × 6 questions). The scores obtained from the six questions for each relationship between waste types are then totaled to obtain the total score for each relationship. This total score is then converted into a relationship strength symbol (A, I, U, E, O, X) .

The waste assessment questionnaire (WAQ) consists of 68 different questions, representing activities, conditions, and behaviors that can generate waste. Questions marked with the word “From” describe types of waste that currently exist and can trigger the generation of other types of waste. Other questions are marked with the word “TO,” meaning that the question describes how each type of currently existing waste may occur as a result of being influenced by other types of waste.

Meanwhile, the scores for the three types of answer options in the questionnaire are divided into two categories. The first category, or Category A, is where a “Yes” answer indicates the presence of waste. The response scores for Category A are: 1 for “Yes,” 0.5 for “Moderate,” and 0 for “No.” The second category, or Category B, is where a “Yes” response indicates that no waste is occurring. The response scores for Category B are: 0 for “Yes,” 0.5 for “Moderate,” and 1 for “No.” Each question on the questionnaire is

divided into several groups. **Table 3** shows the grouping of WAQ questions based on responses, which serves to develop the questionnaire model. The questionnaire results are then processed using an algorithm consisting of several steps developed to assess and rank types of waste[8].

The Waste Assessment Questionnaire (WAQ) was developed to identify and categorize waste generated on the production line. There are eight steps in the waste scoring process to arrive at a final result in the form of a waste ranking. The WAQ consists of eight steps in the waste scoring process to determine the waste ranking, including:

1. Group and count the number of questionnaire items by question type.
2. Perform initial weighting for each type of waste in each questionnaire question type based on the weight values from the WRM.
3. Eliminate the effect of variations in the number of questions for each question type by dividing the weight of each row by the number of grouped questions (Ni) for each question using the following equation (Rawabdeh I. A., 2005):
   $Sj = \sum_{k=1}^{k} \frac{w_{j.k}}{N_i}$ .....Eq. 1
4. Calculate the total score (Sj) based on Equation 3 and the frequency (Fj) of the occurrence of values in each "waste" column, disregarding the value 0 (zero).
   $F_j = N - F_0$.....Eq.2
5. Enter the average score from the responses (attached) from the questionnaire results into each weighting column in the table using the following equation:
   $s_j = \sum_{k=1}^{k} X_k \frac{w_{j.k}}{N_i}$ Eq.3
6. Calculate the total score (sj) based on Equation 5 and the frequency (fj) for each weight value in the "waste" column
   $f_j = N - F_0$.....Eq.4
7. Calculate the initial indicator for each type of waste (Yj) using the following equation:
   $Y_j = \frac{s_j}{S_J}$ x $\frac{f_j}{F_J}$.....Eq.5
8. Calculate the final waste factor value (Yj final) by incorporating the probability factors of influence between waste types (Pj) based on the total "from" and "to" values in the WRM. Express the resulting Yj final values as percentages to determine the ranking of each waste type. Yj final can be calculated using the following equation:
   $Y_{j\,final} = Y_j$ x $P_j \left(\frac{s_j}{S_J} \; x \; \frac{f_j}{F_J}\right) \; x \; (\%From\; j \; x \; \%\; Toj)$.....Eq.6

Failure Mode Effect Analysis

Failure mode and effects analysis (FMEA) is a technique used to identify, define, recognize, and prevent known or potential problems, errors, and other issues in a system, design, process, or service before they reach the consumer. In this context, FMEA focuses on preventing defects, enhancing safety, and improving customer satisfaction[15]. FMEA is used in the design and production processes to reduce costs by identifying product and process improvements early in the development cycle, when changes are easy and This FMEA procedure is conducted by calculating the RPN (Risk Priority Number) to minimize the risk of failure by reducing severity and occurrence and improving detection capability, as explained in the table below. Severity is the first step in determining the level of hazard that may occur in the resulting output. Severity relates to the effects or consequences of a failure mode. Severity is rated on a scale of 1 to 10 for each failure mode, where 1 represents the lowest level and 10 the highest level, which requires further analysis. The following are the severity criteria[9].

Table 2. Severity rating

Rating	Criteria
1	Negligible severity (a negligible adverse effect), we do not need to worry that this consequence will affect the product's performance. Consumers may not even notice this defect.
2	Mild severity (Minor adverse effects). The resulting impact will be minor; consumers will not notice any change in performance. Repairs can be performed during regular maintenance.
3	Moderate severity (moderate negative impact). Consumers will notice a decline in quality, but it remains within acceptable limits. The necessary repairs are inexpensive and can be completed quickly.

Rating	Criteria
4	High severity (Highly adverse impact). Consumers will notice a decline in quality that exceeds their tolerance level. The corrective actions taken are very mahal.
5	Potential severity (Extremely high negative impact). The resulting consequences have a significant
6	impact on other aspects of quality; consumers will not accept them.

Source: International Electrotechnical Commission / IEC (2018)

Occurrence refers to the likelihood or probability of a failure occurring, based on how often potential causes of errors are likely to occur. The likelihood indicated by the occurrence rating is relative rather than absolute. The occurrence rating is measured on a scale from 1 to 10, with the ratings being consistent and continuous. The number of errors that occur is used to indicate the estimated number of errors during the process.

Table 3. Occurrence rating

Rating	Verbal Criteria	Probability
1	It is impossible for this cause to result in a failure	1 in 1000000 1 in 200000
2	Failure will rarely occur	1 in 4000 1 in 1000000
3	A failure is somewhat likely to occur	1 in 4000 1 in 80
4	Failure is very likely to occur	1 in 40 1 in 20
5	It is almost certaint that failures will occur	1 in 8 1 in 2

Source: International Electrotechnical Commission / IEC (2018)

Detection refers to the likelihood of identifying the potential cause of a failure. The rating assigned to detection is a relative rating within the scope of FMEA. To achieve a lower rating, it is necessary to improve the planned detection controls[16]. However, if more than one control can be identified, it is recommended that the detection rating for each control be included as part of the control description. The following is a table of detection ratings:

Table 4. Occurrence rating

Rating	Verbal Criteria	Incidence Rate
1	Prevention and detection methods are very effective. There is no chance that the cause will reappear.	1 in 1000000
2	The likelihood that this is the cause is very low.	1 in 200000 1 in 4000
3	The likelihood of the cause is moderate. Detection methods still make it possible to identify the cause in some cases.	1 in 1000000 1 in 4000 1 in 80
5	It is still highly likely that this is the cause. The detection methods are not very effective, as the problem keeps recurring.	1 in 40 1 in 20
6	The likelihood that this is the cause is very high	1 in 8 1 in 2

Source: International Electrotechnical Commission / IEC (2018)

The Risk Priority Number (RPN) is a measure of relative risk obtained by multiplying the severity, occurrence, and detection values. The RPN is a mathematical system; the threshold values within the scope of FMEA can range from 1 to 1,000. It is not recommended to use the RPN threshold as a basis for determining the need for corrective actions. RPN values range from 1 to 1,000, with 1 representing the lowest possible design risk. RPN values can be used as a guide to identify the most serious issues. Subsequently, recommended actions should be taken with the goal of reducing the criteria that make up the RPN. The RPN value is considered a measure of relative risk and a tool for continuous improvement:

RPN = S x O x D……..Eq.7

3. Results and Discussion

Value stream mapping current state

Based on the observations obtained through process activity mapping, Table 5 shows the activities involved in the margarine packaging process using a packaging machine, with an average duration from P1 to P42 of 41.28 minutes.

Table 5. Process activity mapping

Activity Code	Classification	Waste Indicator	Category	Average Time
P1	O	x	VA	48.46
P2	D	Waiting	NVA	10.91
P3	D	Waiting	NNVA	49.64
P4	D	Waiting	NVA	48.27
P5	T	Transportation	NNVA	36.40
P6	D	Waiting	NVA	36.47
P7	O	Motion	VA	35.15
P8	T	Transportation	NNVA	36.26
P9	D	Waiting	NVA	35.73
P10	D	Waiting	NVA	35.61
P11	O	x	NVA	39.09
P12	I	Defect	NNVA	38.20
P13	O	Overprocessing	NVA	37.91
P14	D	Waiting	NNVA	37.97
P15	T	Transportation	NVA	40.16
P16	D	Waiting	NVA	39.57
P17	D	Waiting	NVA	18.99
P18	I	x	NNVA	54.40
P19	I	Defect	NVA	11.76
P20	O	Overprocessing	VA	54.72
P21	I	Overprocessing	NNVA	53.46
P22	D	Waiting	NVA	54.14
P23	T	Transportation	NVA	51.37
P24	D	Waiting	NVA	61.07
P25	O	x	NNVA	51.85
P26	I	Defect	NVA	52.12
P27	O	Overprocessing	NNVA	50.80
P28	I	Overprocessing	NVA	51.22
P29	D	Waiting	NNVA	51.05
P30	T	Transportation	NVA	45.07
P31	D	Waiting	NVA	44.29
P32	T	Transportation	NNVA	44.45
P33	D	Waiting	NNVA	44.01
P34	I	x	NVA	39.00
P35	D	Waiting	VA	37.74
P36	O	Defect	NNVA	18.72
P37	T	Transportation	NVA	40.46
P38	D	Waiting	NVA	39.63
P39	O	x	VA	40.24
P40	T	Transportation	NNVA	37.98
P41	D	Waiting	NVA	40.07
P42	S	Waiting	NNVA	39.35

Source: Data processing (2026)

Table 6. Summary of activity groups and indicators of waste in process activity mapping

Activity Group	Activity Time	Number of Activities	Percentage
Value Added	216.31	5	12.48
Non-Value Added	872.91	22	50.35
Necessary Non-Value Added	644.52	15	37.18
Total	1733.74	42	100.00
Operation	376.94	9	21.74
Transportation	332.15	8	19.16

Activity Group	Activity Time	Number of Activities	Percentage
Inspection	300.16	7	17.31
Storage	39.35	1	2.27
Delay	685.15	17	39.52
Total	1733.74	42	100
Waste Indicator	Activity Time	Number of Activities	Percentage
Waiting	724.50	18	41.79
Defect	120.80	4	6.97
Transportation	332.15	8	19.16
Motion	35.15	1	2.03
Overprocessing	248.10	5	14.31
x	273.04	6	15.75
Total	1733.74	42.00	100.00

Source: Data processing (2026)

Based on the summary of margarine packaging process activities in table 6, the total activity time was 1,733.74 minutes, consisting of 5 value-added (VA) activities with a total time of 216.31 minutes, 15 necessary non-value-added (NNVA) activities with a total duration of 644.52 minutes, and 22 non-value-added (NVA) activities with a total duration of 872.91 minutes, accounting for the largest percentage at 50.35%. There were 17 delay activities, which accounted for the largest percentage at 39.52%, with an average total activity time of 685.15 minutes.

These NVA activities indicate a waste of time that needs to be eliminated to improve production efficiency. This indicates that the margarine packaging process on the margarine packaging machine has the highest proportion of delay activities among all activities, and indications of waste were detected in the activities occurring on the margarine packaging machine throughout the entire margarine packaging process via process activity mapping, specifically in the areas of waiting, transportation, motion, defects, and overprocessing based on **figure 2**.

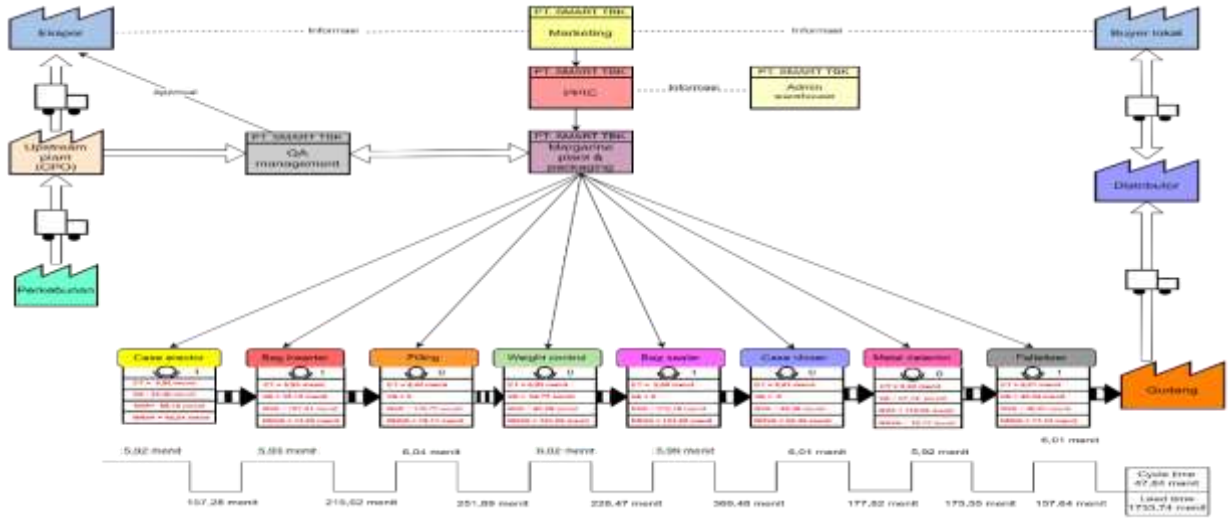


Fig.2: Current value stream mapping
Source: Data processing (2026)

Waste relationship matrix

The waste assessment ws conducted by collecting data through discussions and interviews, as well as by distributing a weighted questionnaire to 1 supervisor and 4 operators involved in the margarine packaging process on the packaging machine. These discussions were held to align perceptions regarding waste and the relationships among different types of waste, resulting in the summary presented in **Table 7**.

Table 7. Summary of the relationships among different types of waste

Correlations Among WasteTypes	Symbol	Score	Strength of Correlation
Waiting_Transportation	W_T	11	I
Waiting_Motion	W_M	12	I
Waiting_Defect	W_D	14	E
Waiting_Overprocessing	W_O	9	I

Correlations Among WasteTypes	Symbol	Score	Strength of Correlation
Transportation_Waiting	T_W	12	I
Transportation_Motion	T_M	6	O
Transportation_Defect	T_D	8	O
Transportation_Overprocessing	T_O	3	U
Motion_Waiting	M_W	6	O
Motion_Transportation	M_T	3	U
Motion_Defect	M_D	7	O
Motion_Overprocessing	M_O	3	U
Defect_Waiting	D_W	12	I
Defect_Transportation	D_T	8	O
Defect_Motion	D_M	10	I
Defect_Overprocessing	D_O	12	I
Overprocessing_Waiting	O_W	9	I
Overprocessing_Transportation	O_T	3	U
Overprocessing_Motion	O_M	4	U
Overprocessing_Defect	O_D	5	O

Source: Data processing (2026)

Table 8 shows that "waiting" has the highest "From" value (25.71%) and the highest "To" value (22.86%). This indicates that "waiting" is the most significant form of waste and the primary factor influencing waste. Meanwhile, "defect" ranks second for both directions of the relationship, with the highest "From" value (22.86%) and the highest "To" value (21.43%). Meanwhile, "motion" has the lowest "From" value, but its "To" value reaches 20.00%, indicating that "motion" receives relatively more connections from other forms of waste than it generates outgoing connections. This suggests that "waiting" has a strong connection with "defect" and relatively balanced connections with the other three forms of waste.

Table 8. Waste matrix value

From / To	W	T	M	D	O	Score	%
W	10	6	6	8	6	36	25.71
T	6	10	4	4	2	26	18.57
M	4	2	10	4	2	22	15.71
D	6	4	6	10	6	32	22.86
O	6	2	2	4	10	24	17.14
Score	32	24	28	30	26	140	100
%	22.86	17.14	20.00	21.43	18.57	100	
Pj faktor	587.76	318.37	314.29	489.80	318.37		

Source: Data processing (2026)

Waste assessment model

Assigning weights to each questionnaire item based on waste relationship matrix (WRM), eliminating the effect of variations in the number of items for each question type, and calculating the total scores and frequencies for each waste type column. The results of the calculations, as shown in table 9, indicate that the largest source of waste occurring in the margarine packaging machine during the margarine packaging process is "waiting" at 28.90%; second is "defects" at 24.34%; third is "overprocessing" at 15.95%; fourth is "motion" at 15.66%; and fifth is "transportation" at 15.14%. Thus, "waiting" and "defects" can be categorized as dominant forms of waste with a high level of criticality.

Table 9. Results of the waste assessment

Initial indicator value (Yj)	W	T	M	D	O
Sj	68	50	50	62	50
Fj	68	68	68	68	68
sj	43.40	30.86	32.34	40.00	32.51
fj	65	65	65	65	65

Initial indicator value (Yj)	W	T	M	D	O
Score (Yj)	0.61	0.59	0.62	0.62	0.62
	W	**T**	**M**	**D**	**O**
Score(Yj)	0.61	0.59	0.62	0.62	0.62
Pj factor	587.76	318.37	314.29	489.80	318.37
Final results (Yj)	358.60	187.83	194.31	302.04	197.90
Final results %	28.90%	15.14%	15.66%	24.34%	15.95%
Ranks	1	5	4	2	3

Source: Data processing (2026)

Failure mode and effects analysis of dominant waste

The results of the FMEA analysis of waste defects indicate that leaks in the top seal occur due to inconsistencies in the thickness of the packaging material, inconsistent inspection of the sealing results, varying machine parameter settings, malfunctions in the vacuum gripper and photoelectric sensors, as well as unstable piston movement and heating temperature. The highest risk was recorded with an RPN value of 240, caused by unstable piston movement due to changes in air pressure and fluctuations in sealing temperature as shown in **Table 10**.

Table 10. Failure mode and effects analysis of dominant waste

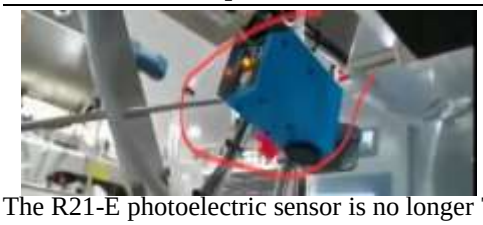
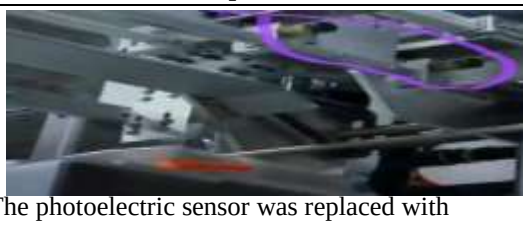
Potential Failure	Severity	Occurrence	Detection	RPN	RPN Classification	Potential Failure	Severity	Occurrence	Detection	RPN	RPN Classification
Failures that cause products to accumulate before sealing and disrupt product supply from the preceding machine.(FMEA Waste waiting)						*Sealing-process disruptions that result in leaks in the package top seal film.(FMEA Waste defect)*					
Machine waiting for packaging material	6	5	4	120	Medium	Variation in packaging material thickness	4	4	5	80	Low
Machine pauses due to component condition or adjustment	6	4	6	144	Medium	Sealing-process disruptions are not addressed promptly	5	5	6	150	Medium
Plastic/packaging film pulling does not operate normally	7	5	5	175	Medium	Sealing setup parameters are inconsistent	6	5	6	180	Medium
The machine mechanism does not operate consistently	8	5	5	200	High	The top-seal rubber pad or thermal insulation is installed incorrectly	8	4	6	192	Medium
Product supply to the Bag Sealer is not synchronized	7	5	6	210	High	The scratch head contacts the case or plastic edge in the wrong position	7	5	6	210	High
The Bag Sealer stops or the sealing cycle fails to run	8	6	5	240	High	The top-seal feed piston moves inconsistently	8	5	6	240	High
						Sealing temperature is unstable	8	5	6	240	High

Source: Data processing (2026)

Lean implementation

Issues with photoelectric sensors must be addressed because these sensors are designed to detect the presence or position of objects according to the machine's design. If a sensor is dirty, misaligned, or malfunctioning, the system may fail to detect objects accurately, potentially causing the process to run improperly. The following corrective actions should be implemented, before operation, the operator checks the cleanliness of the sensor surface, ensures the sensor mount has not shifted, and checks the sensor indicators according to the machine instructions. During operation, when a sensor alarm occurs, the operator records the time of the incident, the alarm code or description, the machine's condition, and the actions taken. Process Safety, technicians evaluate the function of interlocks or automatic shutdowns. Testing is conducted in a controlled manner and in accordance with safety procedures, not by disabling machine safety features as shown in **Table 11**.

Table 11. Table of lean implementation for photoelectric sensors

Before Implementation	After implementation
	
The R21-E photoelectric sensor is no longer standard due to damage to the	The photoelectric sensor was replaced with theSX-61U to align the standardization of the new bag sealer machine.
	
The R21-E photoelectric sensor malfunctioned, causing the product to get stuck in the middle of the bag sealer.	The replacement photoelectric sensor was installed with precision so that the product exits the bag sealer as intended.

Source: Data processing (2026)

4. Conclusion

Based on the results of the study, it can be concluded that there is a dominant waste in the process of packaging margarine in the packaging machine in the form of waste waiting for 28.90% and waste defect of 24.34% which has a high level of criticality. The factors that cause waste include delays in the supply of bags or packaging, operator delays in responding to disturbances ,dirt or dust falling from the top of the machine to the product area, unstable air supply pressure and loose arm parts (plastic pullers), photoelectric sensor error conditions, variations in the thickness of plastic sheet material (bag) and cardboard ,temperature on the heater element that is less stable, the vacuum gripper mechanism is jammed.

Implementation of lean manufacturing to reduce waste on margarine packaging machines include standardization of machine parameters, inspection and maintenance of sealing components, control of material specifications, preparation of inspection checklists, determination of operating parameters based on technical specifications, verification of machine functions after adjustment and improvement of operator competence in responding to machine alarms, checking the quality of sealing results.

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6. Abbreviations

Symbols	Description
N	Number of questions (68)
Ni	Number of grouped questions
K	Question number (ranging from 1 to 68)

XK	Value of the answer for each questionnaire question (1, 0.5, or 0)
Sj	Waste score
Sj	Total for the Waste weight value
Wj	Relationship weight for each type of Waste
Fj	Frequency of non-zero waste (for Sj)
Fj	Frequency of non-zero waste (for sj)
F0	Frequency of 0 (for Sj)

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