Lean Manufacturing Approach for Improvements of Work System in Furniture Factories (A Case Study in PT. Salim Selamat Sempurna)

Aldo Salim[1], Christian[2], Lina Gozali[3], Iveline Anne Marie[4], Frans Jusuf Daywin[5], Agustinus Purna Irawan[6], Harto Tanujaya[7]
[1,2,3,5,8]Industrial Engineering, Universitas Tarumanagara, Jakarta, Indonesia 11440
[4]Industrial Engineering, Universitas Trisakti, Jakarta, Indonesia, 11440
[6,7]Mechanical Engineering, Universitas Tarumanagara, Jakarta, Indonesia, 11440
aldo.545180033@stu.untar.ac.id

Abstract

PT. Salim Selamat Sempurna is a company engaged in furniture manufacturing. Problems occur in the complexity of work systems where there are many non-value-added activities and product defects during the painting process. The research identifies the waste that occurs, including overproduction waste, delay, transportation, motion waste and defective product. The first step in this research is making the current process flow map, current process flow diagram, and current state map. Data processing results show that the value of PCE based on CVSM amounted to 54.356%. In the next stage, waste is analyzed using the Fault Tree Analysis and 5W + 1H analysis. After obtaining the cause of waste, a discussion with the internal company is conducted to obtain a proposal according to the factory's current situation and condition. Given proposals include factory layout redesign by pairwise exchange approach, work order form design, material handling concept selection and drafting painting station concept. At the last stage, a final analysis is conducted to measure the factory efficiency level by making a futures process flow map, a futures flow diagram, and FVSM. Based on the final analysis obtained value of PCE calculation results increased by 8.34% to 62.70%.

Keywords
Lean Manufacturing, Waste, Value Stream Mapping, PCE, Fault Tree Analysis

1. Introduction
Studies and implementation of lean methodologies in businesses are on the rise. Since 2004, there were already 35.7% of plants and factories that have adopted lean, according to the Industry Week/MPI Cencus of Manufacturers, which collected responses from 967 plants (Arabe 2004). Lean manufacturing has been considered by many as a waste reduction technique, but in practice lean manufacturing focuses mainly in maximizing value through minimization of cost (Sundar, Balaji, and SatheeshKumar 2014). Previous studies have also shown the importance of lean techniques in helping companies become more competitive. (Le, Do, and Nam 2010). There are a lot of opportunities lean can offer to manufacturers and implementations can be a necessity for companies while competitors are also taking advantage from implementing lean (Durakovic et al. 2018).

Lean has also been implemented in furniture industries in many departments. One study in 2019 on lean manufacturing analysis in inventory management shows results as high as an eight time reduction (almost 88%) of the finished product inventory (França et al. 2019). Significant positive results may attract more companies to implement lean in their system, but knowledge gaps surrounding this topic still remains, which require further research (Henao, Sarache, and Gómez 2019). PT. Salim Selamat Sempurna is a company engaging in furniture manufacturing, located in Cipondoh, Tangerang. The company operates in an eight-hour shift with one-hour breaks. Production activities of PT. Salim Selamat Sempurna is based on demand from customers (Make to Order/MTO). So in performing their production process, they have to put concern on time doing optimized productions on time. Production processes by PT. Salim Selamat Sempurna is still done manually, in which waste and non-value added activities are found in the production process. Waste and non-value added activity that occurs include: overproduction in the initial assembly of the *classic four-door display case* and the carving production process, delay in the assembly of the *classic four-door display case*, transportation and motion waste in the production floor, and excessive rework caused by the number of the defective product in the painting process.

1.1 Objectives

The company needs to fix the work system on the production floor to reduce waste and remove the non-value-added activity. Besides the problems caused by waste, the company is also facing problems caused by a product defect in the painting process caused by human factors, tools, and the environment.

A method that the company can implement to minimize defects and remove waste and non-value added activities is the Lean Manufacturing approach used to create a fluent product flow along the process value stream and minimize all waste and non-value added activities in the company.

2. Literature Review

Lean manufacturing is a systematic approach used by companies to identify waste to reduce non-value-added activities (Jacobs dan Chase 2008). Lonnie (2010) proposed that an activity can be categorized as a value-added activity if the activity produces something which can change the shape, characteristics, and function of a material or a product. Non-value added activities are categorized as waste and must be removed or minimized to increase profit during the process.

The main principle of the lean approach is the reduction or elimination of waste. Waste can be defined as activities that don't give added value to the company's throughput. Seven types of waste are identified by Shigeo Shingo (Hines and Taylor 2000), which consists of (1) overproduction, (2) defects, (3) unnecessary inventory, (4) inappropriate processing, (5) excessive transportation, (6) waiting, (7) unnecessary motion.

Value stream mapping is a tool used to identify activities that adds value and those that don't (not allow) activities in the manufacturing industry to help find the root of the problem in the process easier. This tool can show errors in a map in the system's current state and use it to create an ideal condition in the future state system (Apel, Yong-Li, and Walton 2007).

Process Cycle Efficiency is a way to measure the efficiency of a factory. By using this matrix, the percentage between the processing time and the overall production time in the factory can be observed (Supriyanto et al., 2012). Process Cycle Efficiency of a factory can be calculated using this formula:

$$PCE = \frac{Value\ Added\ Time}{Total\ Lead\ Time}$$

The 5W+1H analysis is an analysis done to determine the cause of the problem and how to solve them. 5W+1H includes What, Where, Who, When, Why, and How. The 5W+1H analysis is done according to the results of waste identification using the lean concept. After the results are obtained, we can find out what waste is being analyzed, where the waste occurs, who is responsible for the waste, when the waste occurs, why it happens, and how to solve it. (Tapping et al. 2002).

Fault tree analysis is an approach used to identify the cause of a potential failure in the system that leads to an accident. This analysis is conducted from the failures that may happen traced back to all possible causes.

The ARC analysis is required to analyze the level of relationship or connections between activities in its room with the other activities. This analysis helps to determine which activity is to be placed in a certain department; a set relationship degree group is determined and followed by marks for each mentioned degree (Iskandar 2010).

Concept selection is a way to grade the currently used concept and alternative concepts, which will be weighted and ranked later to select the most suitable concept with the criteria required according to the factory condition (Ulrich 2016) .

5S is a term coined in Japan which is related to workplace maintenance (Osada 1995). 5S consists of (1) *seiri* (2) *seiton* (3) *seiso* (4) *seiketsu* (5) *shitsuke*, which is usually translated in English as (1) Sort (2) Set in Order (3) Shine (4) Standardize (5) Sustain.

3. Methods

The methodology is the thought and systematic steps to solve problems and propose improvements from the occurring problems. The flowchart of the research is shown in Figure 1.

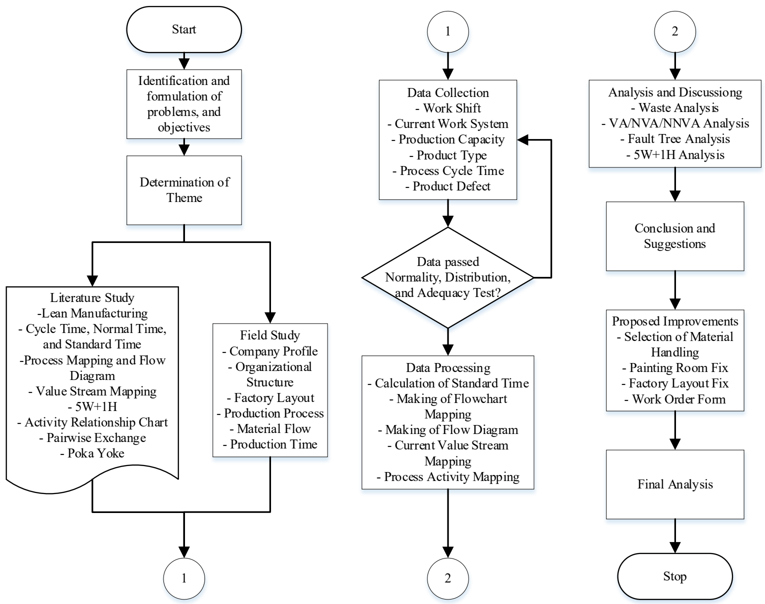


Figure 1: Flowchart of this research

4. Data Collection

Data collection starts by measuring time data from every production process. Processes are broken down into multiple activities done during the production process. Identified processes are shown in Table 1.

Table 1: Identified processses

No.	Activity/Process
1	Moving main material to production area I
2	Measuring and marking multiplex
3	Cutting multiplex using the cutting machine
4	The frame assembly of a *classic four-door display case*
5	Transporting *classic four-door display case* to the painting department
6	Product (*classic four-door display case*) surface sanded using sandpaper
7	Applying wood putty to the product (*classic four-door display case*)
8	*Painting classic four-door display case*
9	Transporting painted *classic four-door display case* to the drying area
10	Waiting for paint to dry
11	Transporting painted *classic four-door display case* transported to the final assembly area
12	Moving resin to the carving production area
13	Making resin mix
14	Pouring resin mix into fibreglass moulding
15	Waiting for carving to dry
16	Transporting dried carving to the final assembly area
17	Measuring and marking glass sheet
18	Cutting glass sheet
19	Drilling glass using a drill
20	Spraying sandblast on glass
21	Transporting glass to the final assembly area
22	Final product assembly
23	Moving assembled product to product warehouse

A total of 23 processes are identified during production. Time measurements are done manually during each identified production activities. The data measured will then be used to calculate cycle time, normal time, and standard time of all activities involved in the production process.

5. Results and Discussion

5.1 Numerical Results

After conducting data collection on every activity, the data goes through normality, distribution, and adequacy tests to ensure that the data used in this research is valid for use in this research. After testing these data, calculations on cycle time, normal time and standard time of every activity in PT. Salim Selamat Sempurna is conducted. Time data, and calculations of cycle, normal, and standard time is shown in Table 2.

Table 2: Calculations of normal time

Time (min)		Process																						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No. Of Observations	1	18.01	11.23	19.92	135.3	4.71	25.22	35.76	182.5	2.451	285.1	15.36	14.96	25.5	10.49	75.04	8.95	5.02	12.62	18.71	10.83	6.31	20.02	13.59
	2	17.91	11	19.5	134.3	4.63	23.1	37.2	184	2.521	290.2	14.68	14.82	24.92	10.21	74.9	8.72	4.8	12.2	18.2	10.88	6.24	20	13.71
	3	18.02	11.19	19.81	135.1	4.84	25.33	33.18	181.2	2.498	279.4	14.98	14.71	25.5	10.3	75.12	8.88	5.12	12.89	18.12	10.91	6.18	20.13	13.68
	4	17.89	10.8	20.41	135.4	4.59	23.75	34.6	181.1	2.412	284	15.12	14.65	24.65	10.88	74.82	8.69	4.9	12.32	18.88	10.4	6.33	19.95	13.71
	5	18.1	10.89	20.33	134	4.73	26.77	37.22	182.3	2.489	280.5	14.89	14.73	24.84	10.91	74.92	8.74	4.94	12.34	18.79	10.55	6.29	19.93	13.62
	6	17.83	11.35	19.78	135.1	4.66	27	36.9	184.3	2.479	269	15.22	14.68	23.1	10.4	75.12	8.99	4.92	12.94	18.27	10.64	6.41	20.17	13.59
	7	18.03	11.3	19.81	135	4.87	26.92	38	183	2.464	281.2	15.34	14.98	24.6	10.55	74.99	9.13	5.13	12.75	18.9	10.76	6.32	19.92	13.58
	8	18.11	11.57	19.62	135	4.54	25.5	34.84	181.9	2.489	280	14.92	15.12	26.2	10.64	75.04	9.21	5.12	12.53	18.52	10.32	6.48	20.03	13.65
	9	18.02	10.9	19.99	135.5	4.72	24.65	35.4	184.8	2.48	288.3	14.84	14.89	23.97	10.76	74.88	9.44	5.1	12.74	18.4	10.4	6.29	20.22	13.67
	10	17.79	10.87	20	134	4.61	24.84	32.2	183.6	2.452	278	14.74	14.88	24.19	10.32	74.87	9.18	5.26	12.29	18.56	10.55	6.12	19.76	13.66
	11	17.98	11.11	19.92	135.2	4.55	23.1	36.42	182.6	2.479	282	15.11	14.65	23.1	10.65	74.98	8.91	5.05	12.4	18.23	10.64	6.32	20.03	13.65
	12	18	11.2	19.71	135.2	4.68	24.6	36.97	183.4	2.466	287.7	15.32	14.97	25.33	10.31	74.9	8.76	4.92	12.53	18.92	10.76	6.19	19.79	13.66
	13	17.89	11.22	20.11	134.4	4.55	26.2	37.26	181.3	2.465	286	14.96	14.96	23.75	10.86	74.87	8.64	4.9	12.38	18.2	10.32	6.21	20.3	13.64
	14	18.3	10.91	20.21	135.1	4.69	24.97	34.24	184.3	2.472	291	14.82	14.85	26.77	10.54	74.8	8.82	5.12	12.6	18.46	10.65	6.42	19.92	13.58
	15	17.83	10.98	20.4	134.9	4.74	24.19	35	182.9	2.449	279	14.71	14.76	27	10.51	75.13	9.13	5.08	12.98	18.2	10.31	6.55	19.83	13.72
	16	18.02	11.49	20.31	135.6	4.63	23.54	37.32	184	2.525	285	14.65	14.84	26.92	10.7	75.22	9.29	5.03	12.18	18.59	10.86	6.36	19.72	13.59
	17	18.02	11.55	19.77	134.5	4.56	27.1	33.1	181	2.488	281.8	14.73	14.98	25.5	10.97	74.92	9.37	4.84	12.78	18.43	10.88	6.21	20.02	13.73
	18	17.92	11.5	19.8	134.1	4.77	26.54	37.22	184.2	2.476	281	15.12	15.12	24.65	10.31	75.01	9.11	5.13	12.32	18.7	10.71	6.14	19.76	13.58
	19	17.89	10.88	19.61	134.2	4.81	25.3	34.87	182.9	2.486	289.9	15.43	14.89	24.84	10.3	74.87	8.96	5.2	12.34	18.34	10.86	6.38	20.04	13.64
	20	18	10.9	19.9	134.7	4.53	26.31	35.81	183.3	2.465	280	15.21	14.88	23.1	10.22	75.19	8.77	5.08	12.94	18.3	10.54	6.22	19.77	13.63
	21	17.99	11.14	19.96	134.3	4.69	27	35	182	2.484	293	14.88	14.65	24.6	10.54	75.18	8.91	5.23	12.75	18.2	10.76	6.36	19.85	13.58
	22	17.88	11.6	20.12	135.9	4.74	24.84	35.48	182.4	2.462	292	14.65	14.97	25.5	10.62	75.12	8.82	4.84	12.53	18.23	10.72	6.43	19.83	13.6
	23	18.09	11.52	20.3	134.8	4.58	23.1	35.1	183.2	2.473	289	14.97	14.96	24.65	10.81	74.82	9.15	5.23	12.8	18.65	10.65	6.58	19.97	13.68
	24	17.99	11.3	20.11	134.4	4.63	24.6	37.9	182.1	2.482	279	15.16	14.77	24.84	10.43	74.92	9.24	5.03	12.36	18.8	10.71	6.33	19.92	13.58
	25	17.89	10.8	19.3	135.1	4.82	25.55	37.22	181.8	2.496	275.2	15.29	14.72	23.1	10.59	75.12	9.39	4.67	12.2	18.3	10.86	6.22	20.03	13.66
	26	18.08	11.19	19.22	135.2	4.59	26.1	36.9	184.8	2.461	274	14.96	14.61	25.5	10.46	74.8	8.9	5.12	12.76	18.96	10.69	6.11	19.94	13.6
	27	17.79	10.91	19.77	134.1	4.61	23.94	38	184.8	2.479	279.8	14.85	14.7	24.65	10.65	75	9.21	4.9	12.2	18.57	10.87	6.28	20.02	13.59
	28	18.09	10.98	19.8	134	4.82	26	34.84	181.8	2.445	278	14.76	14.79	24.87	10	74.9	8.92	4.94	12.77	18.8	10.59	6.17	19.93	13.56
	29	17.91	11.8	19.92	134	4.57	25.53	35.4	183.3	2.466	282.7	14.84	14.68	23.1	10.65	75.2	9.18	4.92	12.56	18.66	10.61	6.21	19.83	13.62
	30	18.1	11.19	20.02	136	4.65	26.01	35.2	183	2.471	283	15.1	14.55	24.6	10.9	75.05	9.42	5.13	12.37	18.34	10.77	6.15	20.04	13.56
Sum		539.37	335.27	597.43	4044.4	140.11	757.6	1074.55	5487.8	74.225	8484.8	449.61	444.72	743.84	316.48	2249.7	270.83	150.67	376.37	555.23	320	188.81	598.67	408.91
Average		17.979	11.176	19.914	134.813	4.670	25.253	35.818	182.927	2.474	282.827	14.987	14.824	24.795	10.549	74.990	9.028	5.022	12.546	18.508	10.667	6.294	19.956	13.630
Adjustment		1.28	0.96	0.96	0.96	1.28	0.96	0.96	0.96	1.28	0.93	1.28	1.28	0.96	0.96	1	1.28	0.96	0.96	0.96	0.96	1.28	0.96	1.28
Normal		23.01	10.73	19.12	129.42	5.98	24.24	34.39	175.61	3.17	263.03	19.18	18.97	23.80	10.13	74.99	11.56	4.82	12.04	17.77	10.24	8.06	19.16	17.45
Allowance		86%	30%	30%	30%	86%	30%	35%	35%	86%	5%	86%	45%	16%	16%	5%	60%	30%	30%	30%	35%	60%	30%	86%
Standard		42.804	13.947	24.853	168.247	11.119	31.516	46.421	237.073	5.890	276.180	35.681	27.513	27.611	11.748	78.740	18.489	6.268	15.657	23.098	13.824	12.889	24.905	32.451

5.2 Graphical Results

The process flow mapping is used to find out more about the material flow from the start until the last activity, work activities, and information about the finishing time of a process or procedure. The current flow process chart of PT. Salim Selamat Sempurna is shown in Figure 2.

FLOW PROCESS CHART

SUMMARY							PROJECT : CLASSIC FOUR-DOOR DISPLAY CASE PRODUCTION	
ACTIVITIES	PRESENT		PROPOSED		SAVING		CHART NUMBER : 01	
	NO.	TIME	NO.	TIME	NO.	TIME	MAN	MATERIAL
OPERATIONS	13	645.2					PRESENT	PROPOSED
INSPECTIONS	-	-					CHARTED BY : CHRISTIAN	
TRANSPORTATIONS	5	186.84					DATE:	
DELAYS	2	354.92						
STORAGES	-	-						
DISTANCE TRAVELED	383.35 m							

PROCESS DETAILS	SYMBOLS ○	□	⇨	D	▽	DISTANCE (m)	TIME (min)		ANALYSIS WHAT	WHERE	WHEN	WHO	HOW	NOTES	ACTION ELIMINATE	COMBINE	CHANGE SEQUENCE	PLACE	PERSON	IMPROVE
Moving main material to production area I			●			83	42.8			✓				NVA						✓
Measuring and marking multiplex	●					-	13.9						✓	VA						✓
Cutting multiplex using the cutting machine	●					-	24.9						✓	VA						✓
Frame assembly of *classic four-door display case*	●					-	168						✓	VA						✓
Transporting *classic four-door display case* to painting department			●			21.74	11.1				✓			NVA						
Product (*classic four-door display case*) surface sanded using sandpaper	●					-	31.5						✓	VA						✓
Applying wood putty to the product (*classic four-door display case*)	●					-	46.4						✓	VA						
Painting classic four-door display case	●					-	237						✓	VA						✓
Transporting painted *classic four-door display case* to drying area			●			11.3	5.89			✓				NVA						
Waiting paint to dry				●		-	276				✓			NNVA						
Transporting painted *classic four-door display case* transported to final assembly area			●			70.87	35.7			✓				NVA						✓
Moving resin to the carving production area			●			65.14	27.5			✓				NVA						✓
Making resin mix	●					-	27.6						✓	VA						✓
Pouring resin mix into fiber glass mold	●					-	11.7						✓	VA						✓
Waiting carving to dry				●		-	78.7				✓			NNVA						
Transporting dried carving to final assembly area			●			41.3	18.5			✓				NVA						✓
Measuring and marking glass sheet	●					-	6.27						✓	VA						✓
Cutting glass sheet	●					-	15.7						✓	VA						✓
Drilling glass using a drill	●					-	23.1						✓	VA						✓
Spraying sandblast on glass	●					-	13.8						✓	VA						
Transporting glass to final assembly area			●			29.13	12.9			✓				NVA						
Final product assembly	●					-	24.9						✓	VA						
Moving assembled product to product warehouse			●			60.87	32.5			✓				NVA						✓
Storing assembled product in product warehouse					●	-	-			✓				NNVA						✓

Figure 2: Current flow process chart

Then, a process flowchart is made to clarify the flow process chart and help in analyzing and further changes in the factory. The current process flowchart of PT. Salim Selamat Sempurna is shown in Figure 3.

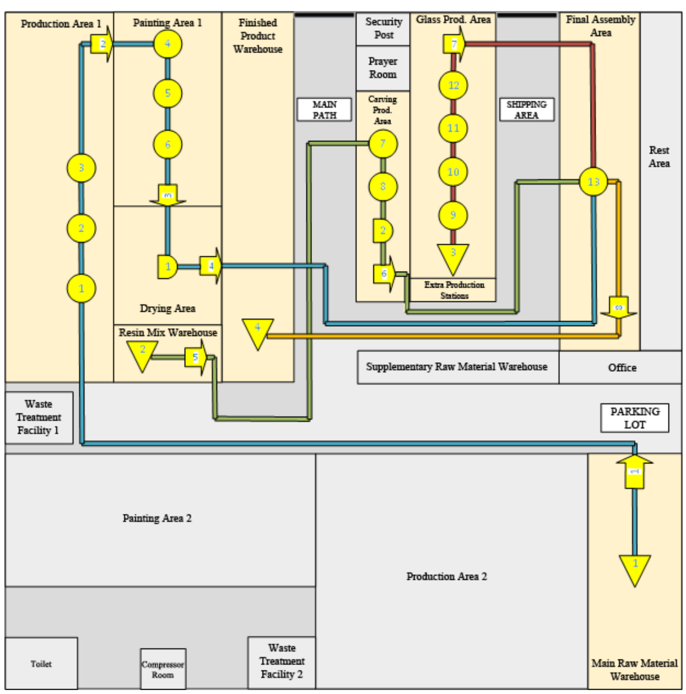


Figure 3: Current process flowchart of PT. Salim Selamat Sempurna

Measuring steps begin by drawing the Current Value Stream Mapping (CVSM). CVSM is used to understand the process in the information flow and physical flow in the production system. Standard time calculated from the tested cycle time data is used in the making of the CVSM. The current state value stream mapping is shown in Figure 4.

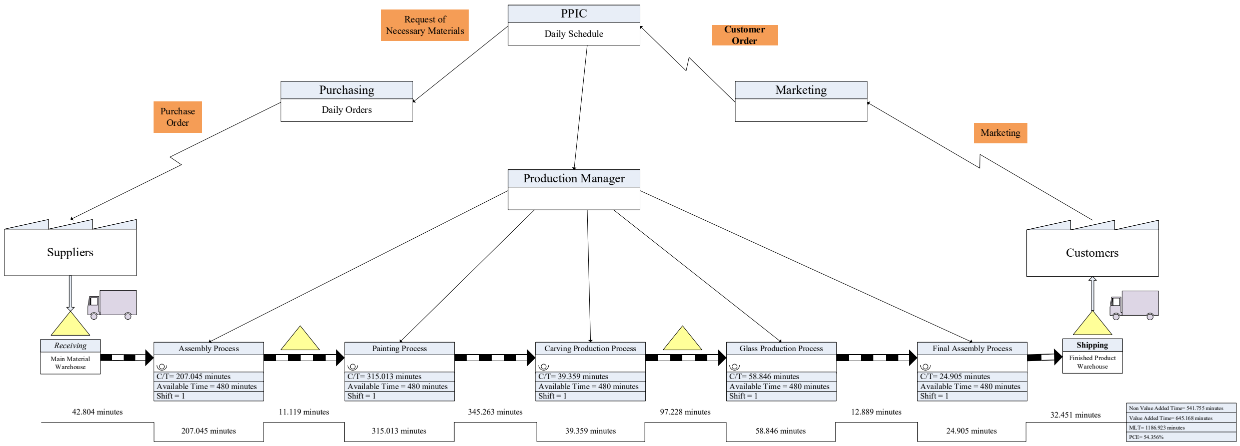


Figure 4: Current state value stream mapping

After making the CVSM, an analysis of the problem root cause of waste occurring on the production floor is conducted. The root cause of waste is analyzed using waste analysis and FTA. The waste analysis is shown in Table 3, and the 5W+1H analysis is shown in Table 4.

Table 3: Waste Analysis

No.	Process Details	Tools / Equipment	Distance (m)	Time (minutes)	VA / NVA / NNVA	Activities							Explanation
						O	D	T	P	I	M	D	
1	Moving main material to production area I	Manual	83	42.8004	NVA			X			X		This transport activity is considered ineffective, due to the long distance between materials and production area. Unnecessary motion is also found, causing inefficiency (travelling distance too long and no transport tools are found)
2	Measuring and marking multiplex	Ruler		13.9472	VA						X		*Hold* ing motion is found in the process, causing inefficiency due to unavailability of transport tools
3	Cutting multiplex using the cutting machine	Cutting Machine		24.8351	VA						X		Non value adding movements such as *reach* ing, *hold* ing, and *position* ing motions are found in the process
4	Frame assembly of *classic four-door display case*	Nails		168.245	VA	X	X						Process takes too much time and employees lack training, causing overproduction and delay
5	Transporting *classic four-door display case* to painting department	Manual	21.74	11.1191	NVA								This activity counts as a non value added activity
6	Product (*classic four-door display case*) surface sanded using sandpaper	Sandpaper		31.516	VA						X		Process takes a long time and stamina, causing employees to tire easily
7	Applying wood putty to the product (*classic four-door display case*)	Putty		46.4206	VA								This activity counts as a value added activity
8	*Painting classic four-door display case*	Airbrush		237.076	VA							X	This activity is considered ineffective, due to the amount of *rework* required due to defective products, caused by the temperature in the environment
9	Transporting painted *classic four-door display case* to drying area	Manual	11.3	5.8905	NVA								This activity counts as a non value added activity
10	Waiting paint to dry			276.178	NNVA								This activity counts as a necessary non value added activity
11	Transporting painted *classic four-door display case* transported to final assembly area	Manual	70.87	35.6810	NVA			X					This transport activity is considered ineffective, due to the long distance between the drying area and final assembly area. There is also no efficient transport tool found
12	Moving resin to the carving production area	Manual	65.14	27.5133	NVA			X					This transport activity is considered ineffective, due to the long distance between materials and the carving production area
13	Making resin mix	Manual		27.6112	VA	X							This activity is focused on work busyness
14	Pouring resin mix into fiber glass mold	Manual		11.7477	VA	X							This activity is focused on work busyness
15	Waiting carving to dry			78.7395	NNVA								This activity counts as a necessary non value added activity
16	Transporting dried carving to final assembly area	Manual	41.3	18.4887	NVA			X					This transport activity is considered ineffective, due to the long distance between the carving production area and final assembly area
17	Measuring and marking glass sheet	Ruler		6.26787	VA						X		Inefficient *hold* ing motion is found due to the use of manual tools
18	Cutting glass sheet	Cutting Machine		15.6570	VA						X		Non value adding movements such as *reach* ing, *hold* ing, and *position* ing motions are found in the process
19	Drilling glass using a drill	Drill		23.0976	VA						X		Inefficient holding motion is found
20	Spraying sandblast on glass	Airbrush		13.8240	VA								This activity counts as a value added activity
21	Transporting glass to final assembly area	Manual	29.13	12.8894	NVA								This activity counts as a non value added activity
22	Final product assembly	Nails		24.9047	VA								This activity counts as a value added activity
23	Moving assembled product to product warehouse	Manual	60.87	32.4511	NVA			X					This transport activity is considered ineffective, due to the long distance between the final assembly area and finished product warehouse, and manual transport processes

Table 4: 5W+1H Analysis

Activity	Analysis	Explanation
1	What	Movement of main material to production area I
	Who	Operator
	Where	Material warehouse
	When	Work element is done in the beginning before starting the production activity
	Why	This transport activity is considered ineffective, due to the long distance between materials and production area. Unnecessary motion is also found, causing inefficiency (travelling distance too long and no transport tools are found).
	How	This activity counts as a non value added activity. To reduce time in this activity, the company can consider buying the correct transporting tools and perform selections before purchasing.
2	What	Measuring and marking of multiplex
	Who	Operator
	Where	Production area I
	When	Work element is done after main materials are prepared
	Why	*Hold* ing motion is found in the process, causing inefficiency due to the use of manual tools.
	How	This activity counts as a value added activity. To reduce time in this activity, the company can implement 5S to reduce inefficient motions such as *hold* ing.
3	What	Cutting of multiplex using the cutting machine
	Who	Operator
	Where	Production area I
	When	Work element is done after markings are made on the multiplex
	Why	Non value adding movements such as *reach* ing, *hold* ing, and *position* ing motions are found in the process.
	How	This activity counts as a value added activity. To reduce non value adding motions, the company can implement 5S to reduce process time and reduce motion waste.
4	What	Frame assembly of *classic four-door display case*
	Who	Operator
	Where	Production area I
	When	Work element is done after the multiplex cutting process
	Why	Process takes too much time and employees lack training, causing overproduction and delay.
	How	This activity counts as a value added activity. Waste occured can be reduced by making company Standard Operating Procedure (SOP) for production to reduce overproduction and delay wastes.
6	What	Surface sanding of product (*classic four-door display case*) using sandpaper
	Who	Operator
	Where	Painting area I
	When	Work element is done in the beginning before the painting process
	Why	Process takes a long time and stamina, causing employees to tire easily.
	How	This activity counts as a value added activity. To reduce time in this activity, work shift changes can be done.
8	What	*Painting* process of *classic four-door display case*
	Who	Operator
	Where	Painting area I
	When	Work element is done after putty is applied on the display case
	Why	This activity is considered ineffective, due to the amount of *rework* required due to defective products, caused by the low temperature, overexposure to the environment, and too much distance between the spraying tube and the compressor.
	How	This activity counts as a value added activity. To reduce defect, identification of the root cause is required, in this case caused by the overexposure of the painting room to the environment, causing failure in meeting the room temperature requirements. Room design can reduce defect.
11	What	Transport of painted *classic four-door display case* transported to final assembly area
	Who	Operator
	Where	Drying area
	When	Work element is done after the drying process of the painted display case
	Why	This transport activity is considered ineffective, due to the long distance between the drying area and final assembly area. There is also no efficient transport tool found.
	How	This activity counts as a non value added activity, Waste reduction can be done by re-layouting the factory, to make the distance between the drying area and final assembly area closer.
12	What	Movement of resin to the carving production area
	Who	Operator
	Where	Material (resin) warehouse
	When	Before carving production process
	Why	This transport activity is considered ineffective, due to the long distance between materials and the carving production area.
	How	This activity counts as a non value added activity, Waste reduction can be done by re-layouting the factory, to make the distance between the resin storage and carving production area closer.
13, 14	What	Production process of carvings
	Who	Operator
	Where	Carving production area
	When	When in the resin production area
	Why	This activity is focused on work busyness.
	How	This activity counts as a value added activity. This activity time can be reduced by applying adjustments on carving production outputs according to internal demands.
16	What	Transport of dried carving to final assembly area
	Who	Operator
	Where	Carving production area
	When	After the carving production process
	Why	This activity counts as a non value added activity, Waste reduction can be done by re-layouting the factory, to make the distance between the carving production area and final assembly area closer.
	How	This activity counts as a non value added activity, Waste reduction can be done by re-layouting the factory, to make the distance between the resin storage and carving production area closer.
17	What	Measuring and marking of glass sheet
	Who	Operator
	Where	Glass production area
	When	Work element is done after the carving production process
	Why	Inefficient *hold* ing motion is found due to the use of manual tools.
	How	This activity counts as a value added activity. To reduce time in this activity, the company can implement 5S to reduce inefficient motions such as *hold* ing.
18	What	Cutting of glass sheet
	Who	Operator
	Where	Glass production area
	When	Work element is done after markings are made on the glass sheet
	Why	Non value adding movements such as *reach* ing, *hold* ing, and *position* ing motions are found in the process.
	How	This activity counts as a value added activity. To reduce non value adding motions, the company can implement 5S to reduce process time and reduce motion waste.
19	What	Drilling of glass using a drill
	Who	Operator
	Where	Glass production area
	When	Work element is done after the glass sheet is cut
	Why	Inefficient holding motion is found due to the use of manual tools.
	How	This activity counts as a value added activity. To reduce time in this activity, the company can implement 5S to reduce inefficient motions such as *hold* ing.
23	What	Movement of assembled product to product warehouse
	Who	Operator
	Where	Final assembly area
	When	Work element is done after final assembly of display case
	Why	This transport activity is considered ineffective, due to the long distance between the final assembly area and finished product warehouse, and manual transport processes.
	How	This activity counts as a non value added activity, Waste reduction can be done by re-layouting the factory, to make the distance between the final assembly area and finished product warehouse closer.

After the waste analysis and 5W+1H analysis, fault tree analysis is conducted to identify the root cause of the defect in the painting process. Fault tree analysis on defective products is shown in Figure 5.

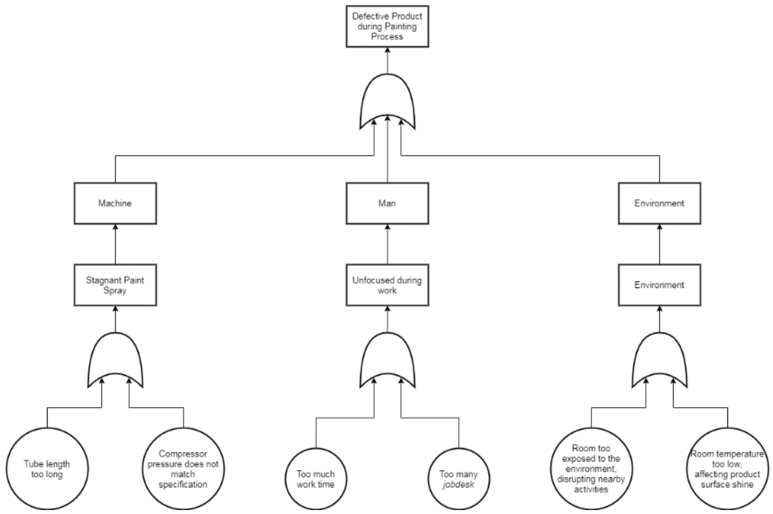


Figure 5: FTA on defective products

5.3 Proposed Improvements

Analysis results are discussed with the company, used as a reference to propose further improvements. Proposed improvements and discussion results are shown in Table 5.

Table 5: Proposed improvements and discussion results

Waste	No.	Activities	Proposed Improvement	Result of Discussion with The Company
Transportation	1	1,11,12,16,23	Design of new layout	Layout redesign may increase production efficiency, but requires a temporary factory. Layout redesign also requires large costs
Motion	2	1	Purchase of tools to help in material transportation	Purchase of tools can be done, if suitable to company needs
	3	2,3,17,18,19	Implementing 5S to reduce inefficient motions	5S concepts are considered good, but implementations may require preparations
	4	6	Addition of changes in work shift	Changes in work shift can be done, but adjustments are also required
Overproduction	5	4	Establishment of production SOP	SOP is already established in the company, but in reality is often ignored
	6	13.14	Adjustment of carving production output according to internal demand	The company has adjusted production output according to demand
Delay	7	4	Conduct of work training	Work training is often conducted, but employees are still often negligent while working
Defect	8	8	Painting room design to minimize defect	Painting room design can be conducted, but implementations must be well thought out

There are some suggestions made after the waste analysis. The first proposal is the change of layout using the activity relationship chart and conducting iterations of movements of the factory facility. Layout changes can reduce time and increase production efficiency. The activity relationship chart is shown in Figure 6.

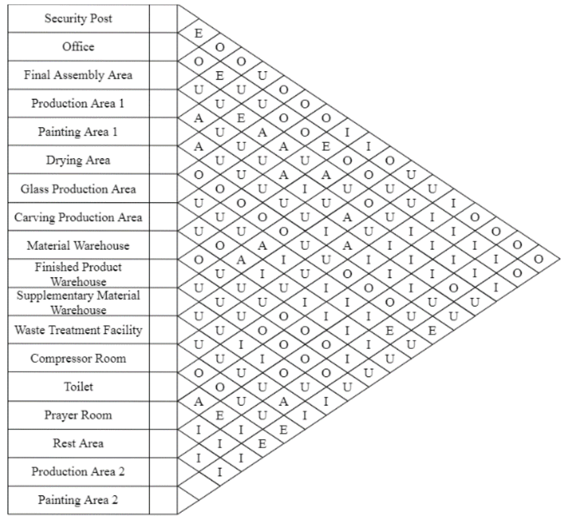


Figure 6: Activity relationship chart

After creating the activity relationship chart, iterations of facility movement is conducted to achieve the designated layout. The proposed factory layout is shown in Figure 7.

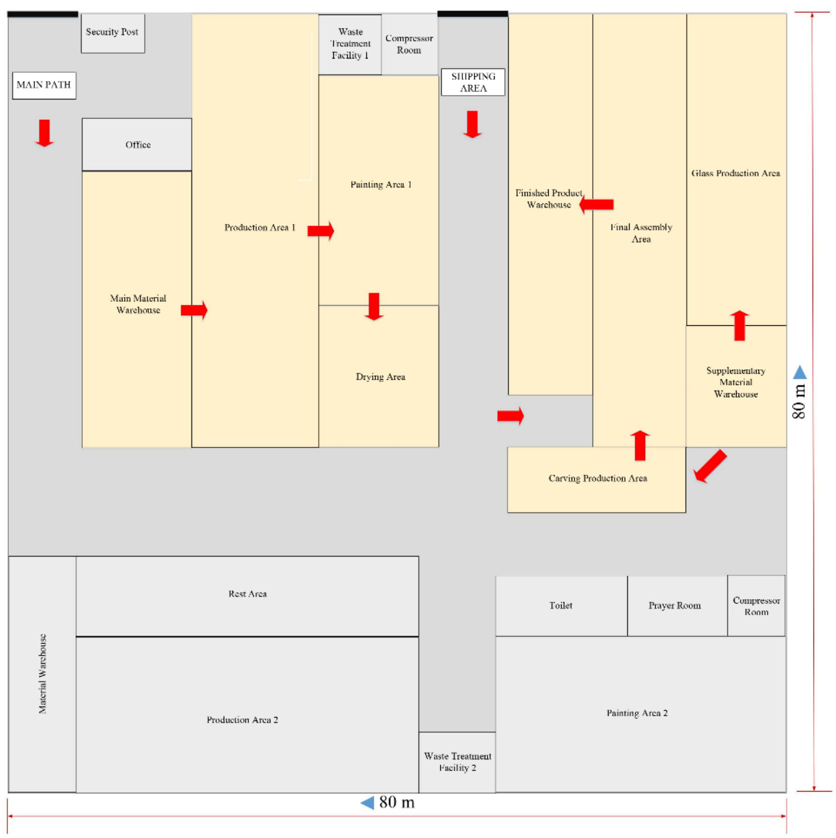
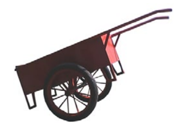


Figure 7: Proposed factory layout

Besides making suggestions on factory layout changes, a couple of proposed action plans are also made, including the change in material handling by selecting and scoring concepts. Material handling concept selection and scoring is shown in Table 6.

Table 6: Concept selection of material handling

Selection Criteria	Weight	Alternatives					
		Steel Hand Trolley 		One Wheeled Wheelbarrow 		Two Wheeled Cart 	
		Score	Weighted	Score	Weighted	Score	Weighted
Function	15%	5	0.75	3	0.45	5	0.75
Load Size	15%	4	0.6	3	0.45	5	0.75
Practicality	10%	5	0.5	4	0.4	5	0.5
Strength	10%	5	0.5	4	0.4	5	0.5
Price	10%	5	0.5	5	0.5	4	0.4
Durability	10%	5	0.5	5	0.5	4	0.4
Treatment	10%	5	0.5	5	0.5	4	0.4
Wheels suitable with terrain	15%	4	0.6	4	0.6	5	0.75
Helps worker during work	5%	3	0.15	4	0.2	5	0.25
Total Score		4.6		4		4.7	
Rank		2		3		1	
Continue?		No		No		Yes	

In the effort of reducing defects, action plans are made to fix of the painting room by concept selection. Painting room concept selections and scoring is shown in Table 7.

Table 7: Painting room score weighting of alternatives

Selection Criteria	Weight	Alternatives					
		Hebel Bricks 		Concrete Bricks 		Red Bricks 	
		Score	Weighted	Score	Weighted	Score	Weighted
Preference	5%	3	0.15	5	0.25	4	0.2
Fire Resistant	10%	4	0.4	4	0.4	5	0.5
Waterproof	15%	4	0.6	4	0.6	4	0.6
Rust Proof	10%	5	0.5	5	0.5	5	0.5
Practicality	10%	5	0.5	5	0.5	4	0.4
Durability	15%	5	0.75	4	0.6	5	0.75
Optimal Room Temperature 33°C	20%	5	1	3	0.6	4	0.8
Price	15%	4	0.6	3	0.45	3	0.45
Total Score		4.5		3.9		4.2	
Rank		3		1		2	
Continue?		Yes		No		No	

To prevent the overproduction of waste on the factory floor, a work order form, as shown in Figure 8, is made.

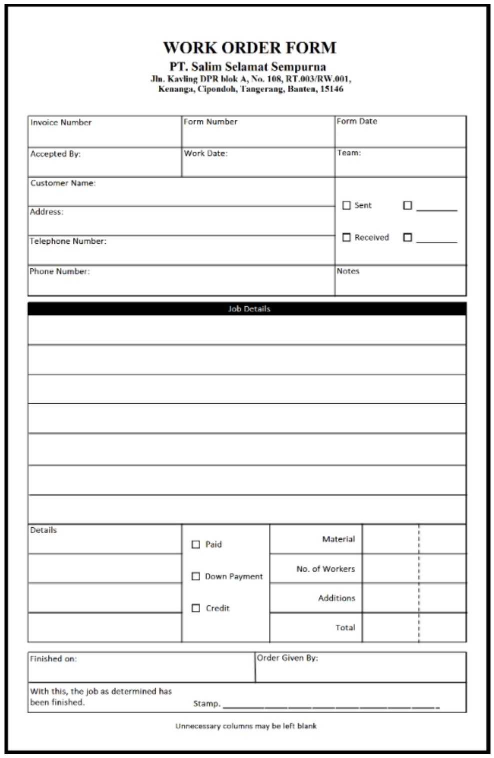


Figure 8: Work order form

5.4 Validation

From the proposed improvements given, a Future Value Stream Mapping (FVSM) is conducted to picture the new flow in perspective of the processing time, which can reduce non-value-added time and increase PCE. From the results of FVSM mapping obtained, then there is a significant increase of productivity in PCE in the FVSM, compared to the PCE in the CVSM, in which the PCE in the CVSM amounted to 54.356% and PCE in the FVSM amounted to 62.7%. FVSM is shown in Figure 9.

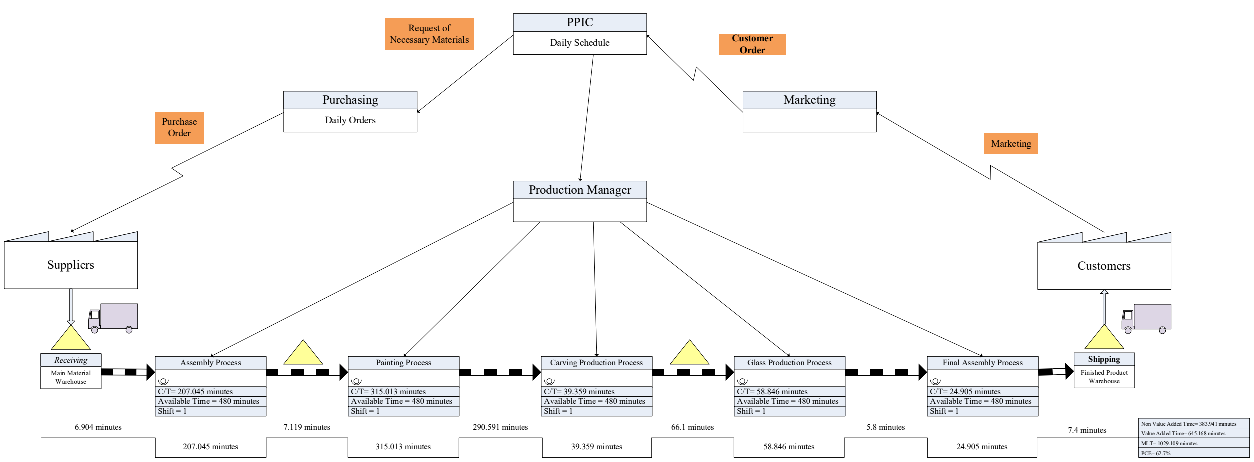


Figure 9: FVSM

6. Conclusions

After conducting a waste analysis, five wastes occurred, including the waste of overproduction, delay, transportation, motion, and defective product. The main cause of waste in PT. Salim Selamat Sempurna is a poor factory layout and other problems caused by the painting room in the painting area being too exposed to the environment, affecting painted product quality and material handling in transport activities.

While making action plans such as creating layouts, an activity relationship chart is made to conduct iterations of factory facility movements. On the other hand, to select material handling and plans for the painting room, concept selections are conducted based on material handling and need in the painting room. Based on concept selection results and weighting of alternative concepts. The best alternative for material handling with a score of 4.7 is the two-wheeled cart, and the best alternative for the design of the painting room is using Hebel bricks. (with a score of 4.5). After measuring the results of proposed improvements from the VSM method, there is a significant increase of productivity in the PCE of the FVSM compared to the PCE in the CVSM, in which the PCE in the CVSM amounted to 54.356% and PCE in the FVSM amounted to 62.7%.

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Biographies

Aldo Salim is a senior-year college student, currently majoring in Industrial Engineering at Universitas Tarumanagara. He graduated from Notre Dame Senior High School in 2018. He has participated as a presenter/speaker in national and international conferences and published conference papers. He has also won collegiate competitions, such as writing competitions (2020, 2021) and poster competitions (2020). He is currently pursuing an academic career after getting his Bachelor's Degree.

Christian is a graduate student from Universitas Tarumanagara, He was granted his Bachelor's degree in 2018, and now he is doing a practical job.

Lina Gozali is a Lecturer in the Industrial Engineering Department of Universitas Tarumangara since 2006 and a freelance lecturer at Universitas Trisakti since 1995. She graduated with her Bachelor's degree at Trisakti University, Jakarta - Indonesia. She got her Master's Degree at STIE IBII, Jakarta – Indonesia, and she recently got her PhD at Universiti Teknologi Malaysia, Kuala Lumpur – Malaysia, in 2018. Her apprentice college experience was in the paper industry at Kertas Bekasi Teguh, shoe industry at PT Jaya Harapan Barutama and automotive chain drive industry at Federal Superior Chain Manufacturing. She teaches Production System and Supply Chain Management Subjects. She researched the Indonesian Business Incubator for her PhD. She has written almost 70 publications since 2008 in the Industrial Engineering research sector, such as Production Scheduling, Plant Layout, Maintenance, Line Balancing, Supply Chain Management, Production Planning, and Inventory Control. She had worked at PT. Astra Otoparts Tbk before she became a lecturer.

Iveline Anne Marie is a Lecturer in the Industrial Engineering Department, Faculty of Industrial Technology, Trisakti University, Jakarta. She received her Master of Mechanical Engineering specificity in Industrial Management from Indonesia University in 1999. Next, in 2012, she received her Doctoral Degree majoring in Agriculture Industrial Technology from Bogor Agriculture Institute. Now she is a Head of the Production System Laboratory. Her research interests include production planning and inventory control, lean manufacturing, product and process design, ergonomic, facility layout design and supply chain management. In 2012 and 2013 She has received research grants from Indonesia Government with the research title Maintenance Decision Support System Installation Of Electricity Transmission System To Improve Service Performance (Study In Distribution & Center Of Control Center Jawa Bali PT PLN) and also in 2017 and 2018 with research title Intelligent Decision Support Systems Design For Uncertainty Handling On Automotive Industrial Supply Chains.

Frans Jusuf Daywin was born in Makasar, Indonesia on 24th November 1942. is a Lecturer in the Department of Agricultural Engineering at Faculty of Agricultural Technology Bogor Agricultural University since 1964 conducted teaching, research, and extension work in the field of farm power and machinery and become a professor in Internal Combustion Engine and Farm Power directing and supervising undergraduate and graduate students thesis and dissertation and retired as a professor in 2007. In 1994 up to present as a professor in Internal Combustion Engine and Farm Power at Mechanical Engineering Program Study and Industrial Engineering Program Study Universitas Tarumanagara, directing and supervising undergraduate student's theses in Agricultural Engineering and Food Engineering Desain. In 2016 up to present teaching undergraduate courses of the introduction of concept technology, research methodology, and seminar, writing a scientific paper and scientific communication, and directing and supervising undergraduate student's theses in Industrial Engineering Program Study at the Faculty of Engineering Universitas Tarumanagara. He got his Ir degree in Agricultural Engineering, Bogor Agricultural University Indonesia in 1966, and finished the Master of Science in Agricultural Engineering at the University of Philippines, Los Banos, the Philippines 1981, and got the Doctor in Agricultural Engineering, Bogor Agricultural University Indonesia in 1991. He joined 4-month farm machinery training at ISEKI CO, AOTS, Japan in 1969 and 14 days agricultural engineering training at IRRI, Los Banos the Philippines, in March 1980. He received the honors "SATYA LANCANA KARYA SATYA XXX TAHUN" from the President of the Republic of Indonesia, April 22nd, 2006, and received appreciation as Team Jury from the Government of Indonesia Minister of Industry in Industry Start-Up 2008. He did several research and surveys in farm machinery, farm mechanization, agricultural engineering feasibility study in-field performance and cost analysis, land clearing and soil preparation in secondary forest and alang-alang field farm 1966 up to 1998. Up till now he is still doing research in designing food processing engineering in agriculture products. Up to the present he already elaborated as a conceptor of about 20 Indonesia National Standard (SNI) in the field of machinery and equipment. He joins the Professional Societies as a member: Indonesia Society of Agricultural Engineers (PERTETA); Indonesia Society of Engineers (PII); member of BKM-PII, and member of Majelis Penilai Insinyur Profesional BKM-PII.

Agustinus Purna Irawan was born in Mataram - Musirawas, South Sumatera, August 28, 1971, is a Lecturer at Universitas Tarumanagara and has served as Chancellor since 2016 until now. Obtained a Bachelor of Mechanical Engineering from the Faculty of Engineering, Gadjah Mada University (1995), a Masters in Mechanical Engineering from the Faculty of Engineering, University of Indonesia (2003), a Doctor of Mechanical Engineering from the Faculty of Engineering, University of Indonesia (2011), Professional Engineer (Ir) Mechanical Engineering from the Faculty of Engineering, Gadjah Mada University (2019) and Professor of Mechanical Engineering from the Ministry of Education and Culture (2014). The fields of scientific research and publication include: Product Design and Development, Strength of Materials, Natural Fiber Composites with implementation in the field of prosthesis and automotive components. Obtaining Research and Community Service Grants for Higher Education / Research and

Technology BRIN / Untar / Others ≥ 100 titles; Patents: 7 and still in process: 4; Copyright: 9 books; Textbooks: 6 books; Book Chapter: 2 chapters; Scientific articles ≥ 100 titles. Obtained a Professional Certificate, namely the Educator Certificate, the Intermediate Professional Engineer Certificate (IPM) of the Indonesian Engineers Association (BKM PII) Vocational Engineer Association (BKM PII), and the ASEAN Engineer Certificate (ASEAN Eng.) From the ASEAN Federation Engineering Organizations (AFEO). He is active in education, various scientific activities, the world of business, professional associations, and various social activities. Received several awards: Best Graduate S2 UI GPA 4.00 cum laude (2003); First best Lecturer Kopertis Region III DKI Jakarta (2011); Best Presentation at the Seminar on Research Results of the Centralized Program, PUPT Dikti (2014); Honorary Member of The ASEAN Federation of Engineering Organizations, AFEO (2018); Best PTS Chancellor for the Academic Leader Award Program (2019).

Harto Tanujaya was born in Pemalang, Central Java, Indonesia on 18th May 1972, is a Lecturer in the Department of Mechanical Engineering at Faculty of Engineering, Universitas Tarumanagara since 2000 conducted teaching, research and has served as Dean of Faculty of Engineering since 2018 until now. Obtained a Bachelor of Mechanical Engineering from the Faculty of Engineering, Universitas Tarumanagara, a Masters in Mechanical Engineering from the Faculty of Engineering, University of Indonesia, and a Doctor of Philosophy (Ph.D.) from the Department of Mechanical Science and Bioengineering, Osaka University, Japan (2011). The fields of scientific research and publication include, Biomechanical, Heat Transfer, Heat Exchanger, Cooling, Numerical Methods. He joins the Professional Society as a member of ASHRAE. Obtaining Research and Community Service Grants from Ministry of Research & Technology and LPPM UNTAR. The publication of national and international scientific articles more than 30 articles.