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IMPLEMENTATION OF LEAN AND GREEN MANUFACTURING IN THE PRODUCTION OF WIFI SECTORAL ANTENNAS AT CV. XYZ

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ABSTRACT

CV. XYZ is a company engaged in manufacturing electronic devices. One of the products produced is the 22 dbi 2.4 ghz MIMO sectoral antenna. With the increasing needs of consumers, the company is trying to optimize the production process in order to have a small lead time. However, in the antenna production line there are still various waste problems that cause a lack of efficiency, effectiveness and optimization of the production process. This study aims to identify waste in the sectoral antenna production process at CV. Global Access Technology and propose improvements based on lean and green manufacturing principles. To reduce the waste that occurs, the Green Value Stream Mapping (GVSM) method, Waste Assessment Model (WAM), Value Stream Analysis TooL (VALSAT), Root Cause Analysis (RCA), and Failure Mode and Effects Analysis (FMEA) are used. From the data processing and analysis that has been done, the most dominant waste identification results are Motion by 25%, transportation by 17.34%, process by 13.77%, overproduction by 12.97%, defect by 12.60%, inventory by 10.37%, and waiting by 8.15%.For environmental aspects, it produces PCB waste of 13 Kg, aluminum sheet by 7 Kg, PVC by 11 Kg. In the company's production process, the improvement recommendations given are investment in industrial oven machines as a substitute for stoves in the PVC heating process and acrylic bending for the PVC bending process, making maintenance cards for CNC machines that experience downtime, making QC cards for the inspection process using QC cards, scheduling the use of lights in the sectoral antenna production line room, making small versions of sectoral antennas for types with PCB waste that can still be reused, recycling PVC waste to make storage shelves and multilevel transportation aids to move antenna components when going to the assembling process.

KEYWORDS *Lean Manufacturing, Green Manufacturing, Waste*

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INTRODUCTION

The growth of public consumption globally cannot be separated from the stimulation of the growth of the manufacturing sector through increased purchasing power and consumptive spending. This is related because the products produced by the manufacturing industry are the result of consumer demand and needs. In June 2023, Indonesia's manufacturing Purchasing Managers' Index (PMI) score reached 52.5 points (Kemenprin, 2023). A reading above 50 indicates expansion or growth in the sector's activity. Despite its positive impact, the intensive activities of manufacturing companies often have a negative impact on the environment, as increased production also means increased use of natural resources, industrial waste and pollutant emissions. The issues of global warming, waste management, and government regulations regarding the environment are starting to tighten and will be a challenge for the industrial world, especially the manufacturing industry, in addition to competition and changes in the business environment that are very fast and dynamic. CV. Global Access Technology is a manufacturing company in the field of networking / network infrastructure that produces WiFi sectoral antennas. In the company there is still waste in the production process of the 22 dbi 2.4 ghz MIMO sectoral antenna, which does not provide added value (Non-Value Added) and there are environmental problems resulting from the production process such as defect waste occurring in the PVC combustion work element, and PVC *bending.* Burning PVC using a stove as a heat source results in uneven temperatures, *motion* waste is found in the PVC *bending* work element. This is because the manual bending process without special tools requires additional inefficient movements, over processing waste is found in the component smoothing work element. Due to repairing previous work that should have been good enough. Component smoothing is carried out on antenna front cover components, waste of waiting for waiting on the graffiti work element of the PCB Feeder manufacturing process, the CNC tool used to make patterns or graffiti on PCBs often overheats, causing damage to the CNC machine and the machine undergoes repair. Making production stop running is due to the lack of routine machine maintenance, causing downtime.

The basis of *lean manufacturing* is to reduce long production process times, the concept of *lean manufacturing* aims to reduce waste throughout production activities. The main goal of this system is to provide the best quality to customers with low production costs and short time. Activities that do not add value are either eliminated (or called non-value-adding activities) or combined with improvements that develop directly (continuous improvement). This process is implemented by facilitating the correct flow of products (incoming goods, processes in production, to the final product), and using a customer pull system to ensure the industry (Firdaus & Wahyudin, 2023). Lean is a philosophy based on minimizing the use of resources and time, in various company activities. lean focuses on identifying and eliminating activities that do not add value in product design, thus providing value to customers. lean is a continuous effort to eliminate (waste) and increase (value added) the value of goods and services (Lestari & Susandi, 2019). Lean manufacturing is a concept that can identify and reduce waste, namely activities that do not add value to a process. By applying the concept of lean manufacturing, the processes in the company can become more effective and efficient so that the company becomes more competitive in its production (Larasati & Laksono, 2022).

Green Manufacturing is basically a system process that does not affect the environment or does not affect it at all. The goal is to increase resilience and pay special attention to environmentally friendly manufacturing (the concept of environmental sustainability) (Prabowo & Suryanto, 2019). The focus of Green Manufacturing according to (Mao et al., 2019). is a high level of efficiency and safety this shows how important stricter environmental policy measures and better accident prevention are. The same method used for lean dimensions is also used for green practices as described by (Fiorello et al., 2023) After mapping, the resulting 9 dimensions of the green framework are as follows:

Table 1 Dimensions of Green Manufacturing

Green
Dimension
EMS (Environmental management system)
LCA (Life cycle assessment)
3Rs - reducing, reusing and recycling
Design for environment
Environmental emission control
Green purchasing
Circular economy, esp. remanufacturing
Environmental collaboration with suppliers/customers
Eco-labelling

(Source: (Fiorello et al., 2023))

(Haleem et al., 2023) revealed that Green Manufacturing is a term for new production methods that aim to reduce negative impacts on the environment through waste reduction, recycling, better utilization of natural resources, and other related measures. According to (Leong, 2019) With the right help, the synergy of Lean and Green can have an impact on operations performance and the environment. Both Lean and Green components are interrelated and work well together to improve manufacturing performance.

Waste refers to work that does not add value to a production process. The concept of reducing waste was introduced and used in the Toyota company. In production, seven classifications of waste were found (Lestari & Susandi, 2019). This is the same as what is revealed (Bell C & Orzen A, 2011). that Every type of waste mentioned is found in all business environments where a lot of activity and energy is spent that does not provide added value The following are seven classifications of waste: defects, waiting, inventory, overprocessing, motion, transportation, overproduction.

Green Value Stream Mapping (GSVM) is a diagnostic tool that simultaneously provides insight into production efficiency (or productivity) and environmental performance and provides the ability to reduce waste and energy use. The advantage of Green Value Stream Mapping is that it allows visualization of the manufacturing process flow and is easy to use compared to similar approaches such as 5 S, Poka Yoke, Kaizen, Kanban, and Just-in-Time to reduce waste, increase value, and reduce energy consumption (Budihardjo & Hadipuro, 2022). A mapping technique used to identify the flow of materials and information about how materials are processed into the final product Where there are two activities in the process flow map, namely adding value and adding no value (Irwan Setiawan, 2021). With process flow maps, production can be grouped into three categories of activities that are worth Valueable Activity (VA), activities that are necessary but not worth Necessarry But Nonvalueable Activity (NBVA), and activities that are not worth Non-Valueable Activity (NVA) (Armyanto, Djumhariyanto, & Mulyadi, 2020). (Herlingga, 2021) revealed that the Current Value Stream Map shows the current condition of the company's production process flow. Current Value Stream analysis is done by calculating lean metrics, namely total lead time and takt time. Meanwhile, the Future Value Stream Map is a company's production flow map that describes the condition of the company's process flow after improvements and waste reduction. a tool that serves to describe the overall system as well as the flow of profits that occur in the company. This requires data such as cycle time, available time, shift, number of operators, and information flow (Nelfiyanti, Saputra, & Puteri, 2023).

(Naziihah, Arifin, & Nugraha, 2022) revealed that the Waste Assessment Model describes the relationship between seven wastes (Overproduction, Process, Inventory, Transportation, Defects, Waiting, and Motion). This model was developed to simplify the search for waste problems and the identification of wastes for disposal. The creation of the Seven Waste Relationship (SWR), Waste Relationship Matrix (WRM), and Waste Assessment Questionnaire (WAQ) are part of the Waste Assessment Model (WAM). The WAM method is used by distributing waste weighting questionnaires to respondents who are responsible for each function of the production operational system (Irawan & Putra, 2021). (Jufrijal & Fitriadi, 2022) revealed that by making direct observations, the WAM method can be used to identify waste at work stations. Direct observation can be done by observing and recording all activities that occur at the workstation.

Value Stream Analysis Tools (VALSAT) has seven tools used to help create Value Stream Mapping, which makes it possible to identify existing weightings in the production process and make improvements related to these weightings. The tool with the highest score will be used to solve existing waste problems and provide a detailed description of the product process (Nugroho & Nandiroh, 2023). (Dhiwangkara & Lukmandono, 2021) revealed that one of the functions of Value Stream Analysis Tools (VALSAT) is to weight the waste that has been identified, then select tools using a matrix. Thus, Value Stream Analysis Tools (VALSAT) can map certain flows to value-added processes.

According to (de Fretes, 2022) a structured method known as Root Cause Analysis (RCA) is used to find factors that influence one or more previous events to be used to improve performance. using RCA in performance improvement analysis can make it easier to track factors that affect performance. In the fishbone diagram, describing the problem in a diagram or image has the aim of making it easier to understand the description of the problem and the factors that cause the problem to appear in the diagram or image.

According to (Amalia et al., 2022) an engineering reliability tool known as FMEA helps detect, identify, prioritize, and eliminate known and/or potential failures of a system, design, or manufacturing process before they reach the customer. This is done by assigning a risk/failure priority number, or Risk Priority Number (RPN). RPN calculations are easier to understand and simpler. Improvement recommendations will be prioritized based on the highest RPN value. There are three variables that make up RPN: Severity, Occurrence, and Detection. The formula for calculating is RPN = Severity x Occurrence x Detection.

Measurements at this stage, aim to measure and find potential causes of non-conformities that occur during the production process. To determine the efficiency of the production process, the first step begins with the calculation of Process Cycle Efficiency (PCE). The PCE calculation formula is as follows:

$$Process\ Cycle\ Efficiency = \frac{Value\ Added\ Time}{Total\ Lead\ Time}\ x\ 100\%$$

PCE calculation is used when mapping the work flow of each work station to obtain information on the PCE value of Current Value Stream Mapping and later recalculation can be done when mapping Future State Value Stream Mapping to compare the increase in production process efficiency after implementing lean implementation (Dewi Yuliana et al., 2023).

RESEARCH METHOD

The research method is a description of the research steps as a framework. thoughts in solving problems so that the research carried out runs systematically and purposefully. (Satria, 2022). In lean and green manufacturing research on wifi sectoral antenna production at CV.XYZ. This research begins with data collection, the data used is primary data and secondary data with the period March 2023 - July 2024. Because in this study the data was obtained by means of observations, interviews, questionnaires, surveys, and experiments depending on the research needs carried out at CV. XYZ.

Some data that has been collected from CV. XYZ include the following: process sequence data in the production line, *cycle time data*. *lead time data*, production capacity data, data on the number of equipment and *man power* at each work station, demand data for the last 1 year, *defect* product data for the last 1 year, WRM questionnaire data, WAQ questionnaire data, and waste data from the production process. After all the required data has been collected, the next stage is data processing with *Lean Manufacturing.*

Lean Manufacturing is an approach that can be used to identify and eliminate waste *through* continuous improvement. (Somantri & Endang Prasetyaningsih, 2021).. There are several stages of data processing with *Lean Manufacturing.* First, *Current State Green Value Stream Mapping* to explain the flow of *the* actual production process. Second, *waste* identification with *Waste Assessment Model* (WAM) consisting of Waste Relationship Matrix (WRM), which is made in the form of a matrix used to analyze measurement criteria. The matrix consists of rows and columns, which analyze the influence of a waste that is affected by other wastes using a scale ranging from very weak to very strong. Third, the conversion to Waste Assessment Questionare (WAQ) calculates the weight of the existing question types of people, machines, and materials that affect the existence of waste. (Setiawan & Rahman, 2021).

Fourth, determining *tools* with the Value Stream Mapping Tool, using Value Stream Analysis Tools (VALSAT). From the VALSAT table, several tools with the largest cumulative score will be selected by ensuring that every waste that occurs is accommodated by the mapping. (Pattiapon, Maitimu, & Magdalena, 2020).. The next stage is analyzing Process Activity Mapping (PAM). There are 3 activities that occur in process activity mapping, namely Value Adding (VA) activity, Non-Value-Adding (NVA) activity, and Necessary Non-Value-Adding (NVVA) activity. Activities will be categorized into several types, namely operation, transportation, inspection, storage and delay. Fifth, *Root Cause Analysis* (RCA) identification aims to determine which root cause of waste must be resolved first. Determination of the root cause of waste using a questionnaire that will be filled in by parties from CV. XYZ (Khunaifi, Rangga Primadasa, & Sugoro Bhakti Sutono, 2022).

Followed by the identification of *Failure Mode Effect Analysis* (FMEA) so that it can provide suggestions for improvement, *Future State Value Stream Mapping*, and the calculation of *Process Cycle Efficiency* (PCE). After the *lean manufacturing* stage is complete, it is continued with an analysis with *Green Manufaturing.*

Green Manufacturing is manufacturing practices that are safe for the environment at every phase of its journey. From the analysis of green manufacturing on the object under study aims to analyze the extent to which the company applies *green manufacturing* in the production process. (Prabowo & Suryanto, 2019). There are several stages of Green Manufacturing analysis, namely identification of production waste generated in production activities. Based on the identification, waste is obtained in activities that do not provide added value. These activities will then be grouped for improvement with the 6R approach (*Reduce, Reuse, Recycle, Recovery, Redesign,* Remanufacturing) for the waste generated.

RESULT AND DISCUSSION

Current State Green Value Stream Mapping

Current state green value stream mapping can provide an overview of the flow of materials and information. The current state value stream mapping in the wifi sectoral antenna production process at CV. XYZ from the results of data processing can be seen in Figure.1 as follows:

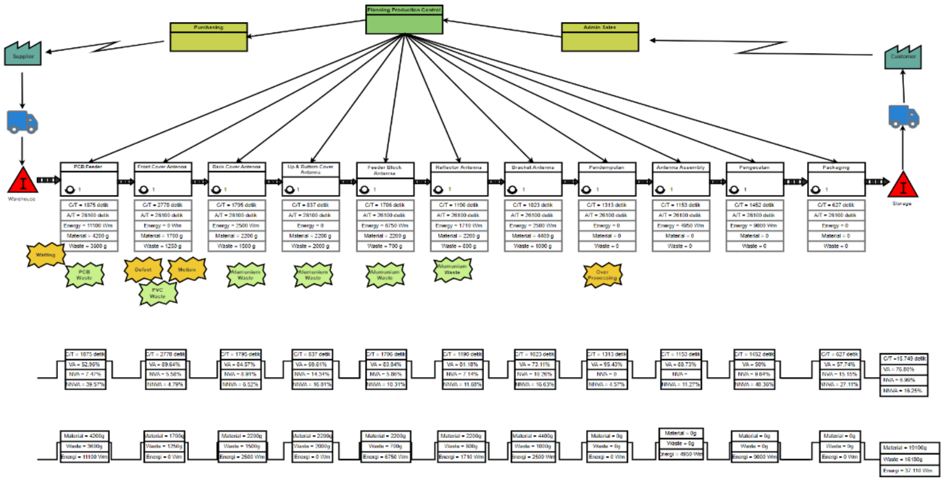


Figure 1. *Current State Green Value Stream Mapping*

Waste Identification

Waste identification is carried out using the Waste Assessment Model (WAM). Waste Assessment Model has 2 steps, namely Waste Relationship Matrix and Waste Assessment Questionnaire. Waste Relationship Matrix is used to determine the degree of relationship between seven wastes using a matrix (Mu'min & Nurbani, 2022).

Waste Relationship Matrix

The *Waste Realtion Matrix* values are as follows:

Table 2. *Waste Matrix Relation Matrix*

F/T	O	I	D	M	T	P	W
O	A	E	O	I	O	X	E
I	E	A	U	E	O	X	X
D	E	A	A	E	I	X	I
M	X	O	O	A	X	I	I
T	O	O	O	I	A	X	E
P	I	U	I	I	X	A	I
W	I	O	O	X	X	X	A

After the weighting is completed and converted into strength symbols, the waste influence level score is calculated using the conversion values A:10, E:8, O:4, U:2, and X:0. The following is the value of the *waste matrix:*

Table 3. *Waste Matrix Value*

F/T	*WASTE*							Score	(%)
	O	I	D	M	T	P	W		
O	10	8	4	6	4	0	8	40	16,3%
I	8	10	2	8	4	0	0	32	13,0%
D	8	10	10	8	6	0	6	48	19,5%
M	0	4	4	10	0	6	6	30	12,2%

T	4	4	4	6	10	0	8	36	14,6%
P	6	2	6	6	0	10	6	36	14,6%
W	6	4	4	0	0	0	10	24	9,8%
Score	42	42	34	44	24	16	44	246	100%
(%)	17,1%	17,1%	13,8%	17,9%	9,8%	6,5%	17,9%		100%

From the calculation of table 2. it is found that *from defects is* 19.50%, *from over production is* 16.30%, and from *transportation* is 14.60%. So that a lot of waste is caused by *defects, over production*, and transportation. Meanwhile, the value of to *motion is* 17.9%, *waiting is* 17.9%, and *inventory* is 17.1%. This indicates that waste in *motion*, *waiting*, and *inventory* is the most waste caused by other waste.

Waste Assessment Questionare

Waste Assessment Questionnaire is used to find out what is the most dominant waste in the wifi sectoral antenna production system at CV. XYZ. The value of the WAQ results is as follows:

Table 4. *Waste Assessment Questionnaire* (WAQ) Calculation Results

Waste	**O**	**I**	**D**	**M**	**T**	**P**	**W**
Yj (*Score*)	1	1	1	1,217	1,560	1,549	1
Pj *Factor*	0,028	0,022	0,027	0,022	0,012	0,010	0,017
Yj Final	0,014	0,011	0,013	0,027	0,019	0,015	0,009
Final Result (%)	12,97	10,37	12,60	24,80	17,34	13,77	8,15
Rank	4	6	5	1	2	3	7

In table 4. obtained the value of Yj (*Score*), Pj *Factor*, Yj *Final*, *Final Result* (%), and *Rank* for each existing waste. The calculation results in table 4.18 will be depicted in graphical form to find out the dominating waste from the WAQ questionnaire.

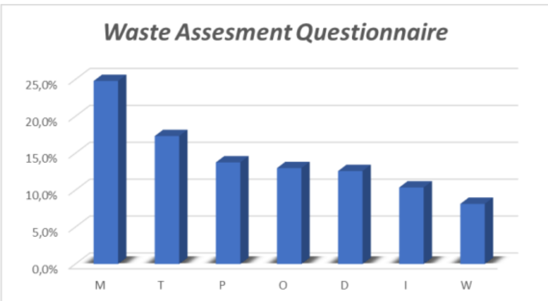


Figure 4. Graph of *Waste Assessment Questionnaire*

From the graph above, the percent value for waste that dominates the production process in the company is obtained. *Motion* by 25%, *transportation by*

17.34%, *process by* 13.77%, *overproduction by* 12.97%, *defect* by 12.60%, *inventory by* 10.37%, and *waiting by* 8.15%.

Value Stream Analysis Tools

VALSAT is an approach used by calculating the weight of waste, then from the determination of the weight, the selection of instruments using a matrix is carried out. The following are the results of VALSAT:. The following are the results of the VALSAT weighting below:

Table 5. Weighting Results of VALSAT *Tools*

Waste	***Score***	***Mapping Tools***						
		PAM	***SCRM***	***PVF***	***QFM***	***DAM***	***DPA***	***PS***
Defect	12,60%	12,6	0	0	113,4	0	0	0
Over Production	12,97%	12,97	38,91	0	12,97	38,91	38,91	0
Waiting	8,15%	73,35	73,35	8,15	0	24,45	24,45	0
Over Processing	13,77%	123,93	0	41,31	13,77	0	13,77	0
Motion	24,80%	223,2	24,8	0	0	0	0	0
Inventory	10,37%	31,11	93,33	31,11	0	93,33	31,11	10,37
Transportation	17,34%	156,06	0	0	0	0	0	17,34
Total	**100%**	**633,22**	**230,39**	**80,57**	**140,14**	**156,69**	**108,24**	**27,71**

In table 5. above that *Process Activity Mapping* (PAM) has the largest score of 633.22 of the other 6 tools. PAM is a tool used to eliminate waste or non-value-added activities. involves mapping each activity in a process to identify areas that generate value and areas that do not generate value (waste). Thus, companies can reduce or eliminate unnecessary activities and improve overall process efficiency. Total PAM time in the CV sectoral antenna production process. XYZ from the calculation results in each activity as follows:

Table 6. Total PAM Time of Wifi *Sectoral* Antenna Production

Activities	**Total**	**Total Time (Seconds)**	**Percentage**
Operation	36	11.999	76.20%
Transportation	50	1.735	11.02%
Inspection	1	112	0.71%
Storage	1	60	0.38%
Delay	19	1.843	11.70%
Total Time / *Cycle Time*		**15.749**	
Value Added (VA)	36	12.091	76.78%
Non Value Added (NVA)	18	865	5.49%
Non Necessary Value Added (NNVA)	54	2.793	17.73%

From table 6. it is known that in the Wifi *sectoral* antenna production process, the *operation* activity takes 11,999 seconds with 36 number of *operations* from the total production time as a whole. The next activity is *transportation* spending 1,735 seconds with 49 *transportation counts*, 112 seconds inspection with 1 inspection count, 60 seconds *storage* with 1 *storage count*, and delay, 1843 seconds with 19 delay counts. *Value Added* activities with a percentage of 76.80%, *Non Value Added* 6.99%, and Non *Necessary Value Added* 16.25%.

Value Added Ratio = $\frac{Vaue\ Added\ Time}{Total\ Process\ CT}$ x 100% =

$$= \frac{12.091}{15.749} \text{ x } 100\% = 76.70\%$$

After identifying *Process Activity Mapping*, *the* next step is to identify the use of materials and waste generated from each production activity in the company. The use of materials generated from the production process is as follows;

Table 7. Identification of Material Usage

Activities	***Waste* Type**	**Materials Total**	**Materials Used**	***Waste***	**Percentage of *Vaue Added***	**Percentage of *Non Value Added***
PCB Manufacturing	PCB	4200g	600g	3600g	14.29%	85.71%
Front Cover Creation	PVC	1700g	450g	1250g	26.47%	73.53%
Back Cover	Aluminum	2200g	700g	1500g	31.82%	68.18%
Up & Button Cover	Aluminum	2200g	200g	2000g	9.09%	90.91%
Feeder Block	Aluminum	2200g	170g	2030g	7.73%	92.27%
Reflector	Aluminum	2200g	300g	1900g	13.64%	86.36%
Bracket	Iron plate	4400g	500g	3900g	11.36%	88.64%
Total		19100g	2920g	16180g	15.29%	84.71%

Based on table 7. identification of material usage for one sectoral antenna production above, it can be seen that the percentage of *value added* PCB is 14.29%, *front cover is* 26.47%, *back cover is* 31.82%, *up* & *buttom cover is* 9.09%, *feeder block is* 7.73%, *reflector is* 13.64%, *bracket is* 11.36%.

The energy identification process is carried out to determine the use of electrical energy used by tools that use electrical resources. The following is the use of energy generated from the production process.

Table 8. Identification of Energy Usage

Activities	**Machine**	**Power (*watts*)**	**Time (minutes)**	**Total energy use Wm**

PCB manufacturing	CNC Machine	1110	10	11.100
Iron plate cutting	Seated grinding	250	10	2500
Aluminum cutting	Hand grinding	570	3	1710
Assembly punching	Hand drill	450	11	4950
Feeder block punching	Drill press	750	3	6750
Splicing	Solder	100	11	1100
Painting	Compressor engine	750	12	9000

From table 8. the identification above can be seen the energy use of the machines used. PCB manufacturing activities using CNC machines use a total energy of 11,100 Wm, aluminum cutting activities using sitting grinders of 2500 Wm, iron plate cutting activities using hand grinders of 1710 Wm, part punching activities during assembly using a hand drill of 4950 Wm, feeder block punching activities using a drill press of 6750 Wm, connection activities during assembly using 1100 Wm solder, and painting activities using a 9000 Wm compressor machine.

Followed by the identification of *seven wastes* in the company based on the *current state value stream mapping of the* CV sectoral antenna production process. XYZ which causes the production *lead time* to be long. The analysis was carried out from the results of interviews and direct observations with the company. The *seven wastes* contained in CV. XYZ are as follows.

Root Cause Analysis (RCA) Identification

1. *Fishbone* Diagram of *Over Production*

Fishbone diagram is done to categorize the causes of the problem. Based on interviews and root cause analysis, *over production* occurs due to several causes, namely *man, methods*, *materials,* and *measurements.*

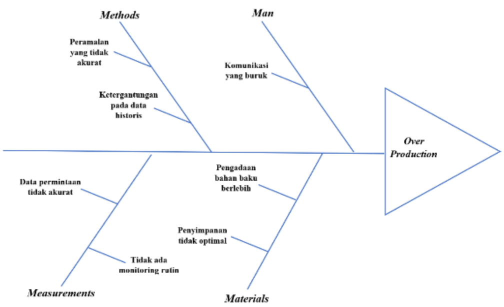


Figure 2. *Fishbone* Diagram of *Over Production*

Based on the *fishbone* diagram above, the *major causes* that occur in *waste over production* can be identified. *Man is* caused by poor communication; *methods* *are caused* by inaccurate forecasting and reliance on historical production data; *materials are* caused by excessive procurement of raw materials and non-optimal storage; *measurements are* caused by inaccurate demand data and no routine monitoring.

2. *Fishbone* Diagram of *Waiting Time*

Fishbone diagram is done to categorize the causes of the problem. Based on interviews and root cause analysis, *waiting time* occurs due to several causes, namely *man*, *machine*, *methods*, *materials environment.*

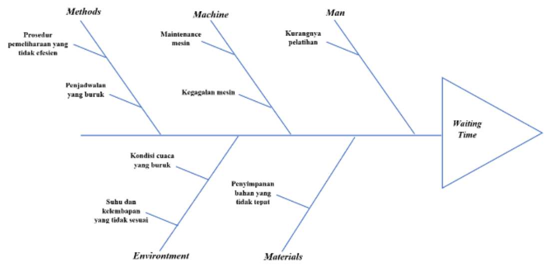


Figure 4.3 *Fishbone* Diagram *Waiting Time*

Based on the *fishbone* diagram above, it can be seen the *major causes* that occur in *waste waiting time. Man is* caused by lack of machine operator training; machine is caused by machine *maintenance* and machine failure during processing; *methods are caused* by inefficient machine maintenance procedures and poor *maintenance* scheduling; *materials are* caused by improper storage of *materials*; *environment is caused by poor* weather conditions and inappropriate humidity temperatures.

3. *Transportation Fishbone* Diagram

Fishbone diagram is done to categorize the causes of the problem. Based on interviews and root cause analysis, *transportation* problems occur due to several causes, namely *man*, *machine, methods*, *materials,* and *environment.*

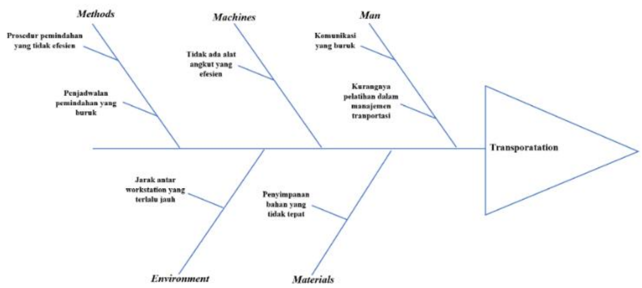


Figure 4.4 *Fishbone* Diagram *Transportation*

Based on the *fishbone* diagram above, the *major causes* that occur in *waste transportation* can be identified. *Man is* caused by poor communication and lack of training in transportation management; machines is caused by no efficient means of transport; methods is caused by inefficient transfer procedures and poor transfer scheduling; materials is caused by improper storage of materials; environment is caused by workstations that are too far apart.

Identification of *Failure Mode & Effect Analysis* (FMEA)

FMEA (*Failure Mode* & *Effect Analysis*) is a technique for determining the conditions under which a system might fail and the effects of that failure are identified. The results of the FMEA questionnaire that has been filled out to CV. Global Access Technology.

Table 9. FMEA Questionnaire Score

Failure Mode	***Potential Effect***	***Severity***	***Potential Cause***	***Occurance***	***Control***	***Detection***	***RPN***
Uneven heat in PVC combustion	Uneven and out-of-specification PVC surfaces or defects	8	Use of stoves not designed for PVC	10	Observation during combustion	2	160
Manual PVC leveling (stamping)	Uneven surface, rework (caulking)	8	No special tools for PVC equalization of the front cover part	10	Visual observation after grading and spreading	2	160
Errors in PVC bending	The bending result is not perfect	9	Using unsuitable bending tools (for iron/aluminum)	10	Visual observation after bending	2	180
CNC machine failure	Production delay, waiting time, defective products	10	Irregular machine maintenance	8	Routine maintenance and inspection of machines	2	160
Waiting for CNC machine repair	Production is delayed on a line	8	There is no regular maintenance schedule for CNC machines	5	Replacement of CNC machine parts	4	160

Waiting for the repair of the defective antenna part (front cover)	Waiting time, and the assembling process is hampered	7	The absence of special tools at the time of burning and equalization, causing rework (pedempulan)	10	No recommendations given by the company	1	70
Non-optimized QC process	Defective products are not detected	6	Lack of standardization in the QC process	6	Manual inspection and manual QC record keeping	6	180
Taking antenna parts to the old assembling floor	Delivery of finished products to the painting floor takes a long time	5	Poor layout mapping and limited amount of material handling	10	No recommendations given by the company	2	100
Demand forecasting inaccuracies	Excess or lack of raw material inventory	6	Simple forecasting methods, lack of accurate historical data	6	Current forecasting method	5	180
Inefficient material transfer	Delayed production time	6	Non-optimal facility layout, too much distance between workstations	10	Current layout	2	120

Based on the results of the questionnaire above, the RPN value obtained is a problem that has priority in making improvements. In the production process, problems with high RPN values are obtained including: uneven heat in PVC combustion, PVC equalization by manual means (stepped on), errors in bending PVC after the equalization process, waiting for CNC machine repairs, undetected defective products, and inaccuracies in demand forecasting.

Proposed Improvement Recommendation

1. Based on the calculation of the RPN value, there are several failure modes that fall into the defect category including uneven heat in burning PVC, equalization of PVC manually (stepped on), errors in bending PVC after the equalization process. For this problem, it can be proposed to use an ABS acrylic bending machine. The main objective in this improvement is to reduce defects that occur due to the PVC heating process using a stove where the heat generated by the stove cannot be evenly distributed which results in high defects arising.

2. Preventive maintenance cards are used to schedule and track preventive maintenance activities that are performed regularly to prevent machine breakdowns. This card can contain Maintenance dates, types of tasks to be performed, who is responsible, and inspection results and Periodic maintenance cards are used for maintenance that is carried out at certain time intervals, such as weekly, monthly, or annually. This card contains the date of periodic maintenance, the type of tasks to be performed, and the inspection results.
3. Recommendations for improvements that can be made are to use QC cards for each inspection process which later this card will be attached to each product produced. Where this can eliminate the process of filling out the QC book. This card serves as proof that the inspection has been carried out and the product meets the set quality standards. This can also reduce the use of paper waste generated from each QC historical book filler.

Proposed Recommendations for Improvement of Environmental Aspects

Environmental Aspects	Proposed Improvements	Environmental impact	Required Action
Energy consumption	Use of energy-efficient equipment	Reduce energy consumption and carbon emissions	Replacing old equipment with more efficient ones, such as high-tech industrial ovens
	Scheduling the use of machines/tools that use electrical energy	Reduce electrical energy consumption	Not all work stations can use lights/lighting devices. But can utilize incoming sunlight
Solid Waste	Implementation of 6R program (*Recoverable, recorvery, redesign, reuseable, remanufacture, recylce*)	Reduce the volume of waste disposed to landfills	Create a recycling program for leftover PVC and aluminum pieces
	Manufacture of 20 dBi 5.8 GHz mini sectoral antenna	Reduce PCB waste volume	Creating a mini version of the sectoral antenna
Drying Process	Uses efficient, weather-independent drying technology	Reduced dependence on weather	Investment in industrial ovens for PCB drying

		conditions and carbon emissions	and painting processes

Future Process Activity Mapping (PAM)

Activities	Total	Total Time (Seconds)	Percentage
Operation	36	11.999	86.99%
Transportation	37	1.270	9.21%
Inspection	1	112	0.81%
Storage	1	60	0.44%
Delay	6	355	2.57%
Total Time / *Cycle Time*		**13.796**	
Value Added (VA)	36	12.091	87.62%
Non Value Added (NVA)	0	0	0 %
Non Necessary Value Added (NNVA)	41	1.705	12.37%

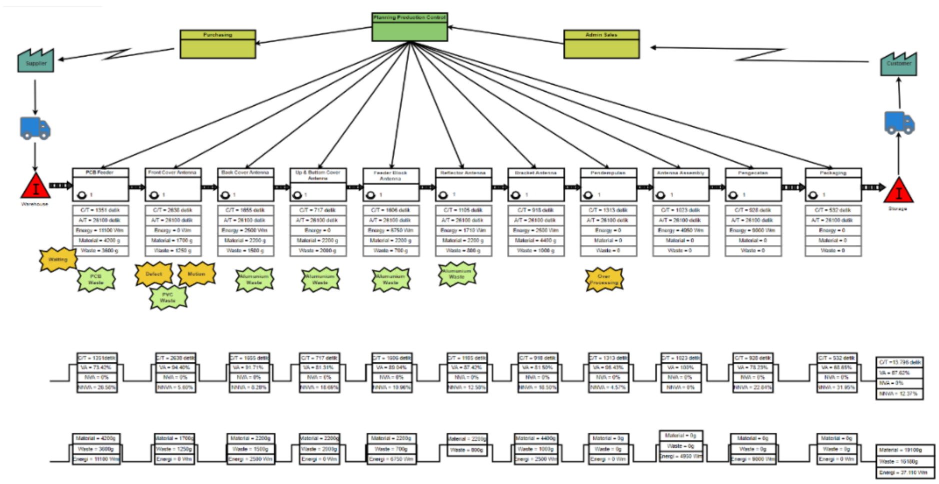
It is known that in the Wifi *sectoral* antenna production process, the *operation* activity takes 11,999 seconds with 36 *operations* out of the total production time. The next activity is *transportation* spending 1,270 seconds with 37 *transportation*, 112 seconds inspection with 1 inspection, 60 seconds *storage* with 1 *storage*, and delay, 355 seconds with 6 delays. *Value Added* activities increased after the elimination of non-value added activities with a percentage of 87.62%, *Non Value Added* 0%, and Non *Necessary Value Added* 12.37%.

$$\textit{Value Added Ratio} = \frac{\textit{Vaue Added Time}}{\textit{Total Process CT}} \text{ x } 100\% = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$= \frac{12.091}{13.796} \text{ x } 100\% = 87.62\%$$

Future State Value Stream Mapping

The value stream mapping image of wifi sectoral antenna production at CV. XYZ after waste elimination:



CONCLUSION

Based on the identification that has been carried out, there are several wastes that occur in the CV wifi sectoral antenna production line. Global Access Technology which is caused by *defects*, *waiting time*, and *over process*. The Green Value Stream Mapping results show an increase in production lead time or value added time. From a total lead time of 15,749 seconds to 13,796 seconds or an increase in value added time from 76.78% to 87.62%. Experienced an increase in value added time of 10.84%.

The proposed improvement recommendations given to the Wifi sectoral antenna production process are investment in industrial oven machines as a substitute for stoves in the PVC heating process and acrylic bending for the PVC bending process, making maintenance cards for CNC machines that experience sudden downtime, making QC cards for the inspection process using QC cards for each inspection process which later this card will be attached to each product produced. Where this can eliminate the process of filling out the QC book. This card serves as proof that the inspection has been carried out and the product meets the set quality standards, for environmental aspects The use of energy-efficient equipment such as the use of industrial ovens, Scheduling the use of machines/tools that use electrical energy such as the use of lights that require high accuracy, Implementation of the 6R program (*Recoverable, recorvery, redesign, reuseable, remanufacture, recylce*) by creating a recycling program for PVC and aluminum scraps. Using efficient and weather-independent drying technology by investing in industrial ovens and mini-making 20 dBi 5.8 GHz sectoral antennas from leftover PCB waste.

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