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Lean Manufacturing Analysis Using Waste Assessment Model (WAM) and Root Cause Analysis (RCA) Methods

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Abstrak

Pesatnya perkembangan ilmu pengetahuan dan teknologi di dunia industri menyebabkan persaingan antar industri semakin ketat. Hal ini membuat industri harus meningkatkan produktivitasnya baik dari segi proses maupun hasil. Sampah merupakan masalah besar dalam dunia industri. Salah satunya terjadi pada industri tisu di Jawa Timur. Dimana produksi tisu handuk merupakan salah satu barang produksi yang diproduksi paling besar. Observasi yang dilakukan mengidentifikasi 32 jenis sampah yang dikategorikan menjadi tujuh sampah. Waste Assessment Model (WAM) merupakan metode yang cocok untuk mengidentifikasi pemborosan kritis yang terjadi, Value Stream Mapping untuk pemetaan, Root Cause Analysis untuk menemukan akar penyebab permasalahan, dan 5W1H untuk memperkuat permasalahan dan memberikan saran perbaikan. Hasil perhitungan dan analisis metode Waste Assessment Model (WAM) diperoleh jumlah waste kritis terbesar yaitu cacat sebesar 20,31%, sebesar 18,59%, dan Gerak sebesar 15,30%. Akar permasalahan yang terjadi adalah kondisi mesin dalam keadaan tidak optimal umurnya dan kurangnya perawatan, belum adanya SOP yang mengatur cara menjaga tatanan yang sesuai, kesalahan manusia dalam penyetelan mesin rewinder, dan perlunya upgrade mesin. Sehingga beberapa rekomendasi perbaikan yang dapat dilakukan adalah mulai dari pengembangan SOP, pelatihan dan monitoring, peningkatan berbagai fasilitas, dan otomatisasi mesin. Hasil Value Stream Mapping (VSM) menunjukkan Value Cycle Efficiency (PCE) setelah perbaikan meningkat dari 45,26 menjadi 64,38%. Hal ini menunjukkan keberhasilan rekomendasi perbaikan dalam menyelesaikan berbagai pemborosan dan meningkatkan efisiensi proses yang ada.

Kata Kunci : industri tisu handuk, sampah kritis, produksi, optimalisasi

Abstract

The rapid development of science and technology in the industrial world, causing competition between industries to be tighter. This makes the industry to increase productivity both in terms of process and results. Waste is a big problem in the industrial world. One of them occurred in a tissue industry in East Java. Where the production of towel wipes is one of the largest produced production items. The observations made identified 32 types of waste categorized into seven waste. Waste Assessment Model (WAM) is a suitable method to identify critical waste that occurs, Value Stream Mapping for mapping, Root Cause Analysis to find the root cause of problems, and 5W1H to reinforce problems and provide suggestions for improvement. The calculation and analysis results of the Waste Assessment Model (WAM) method obtained the largest amount of critical waste, namely defects by 20.31%, by 18.59%, and Motion by 15.30%. The root cause of the problem that occurs is the condition of the engine in a state that is not optimal age and lack of maintenance, the absence of SOPs that regulate how to maintain the appropriate order, human errors in the rewinder engine setup, and the need for engine upgrades. So that some recommendations for improvements that can be made are starting from the development of SOPs, training and monitoring, upgrading various facilities, and machine automation. The results of Value Stream Mapping (VSM) showed that the Value Cycle Efficiency (PCE) after improvement increased from 45.26 to 64.38%. This shows the success of improvement recommendations in resolving various wastes and increasing the efficiency of existing processes.

Key words *: towel tissue industry, critical waste, production, optimilization*

INTRODUCTION

The rapid development of science and technology in the industrial world, causing competition between industries to be tighter. This forces industries to increase productivity both in terms of process and results. With the increasingly fierce competition, it will require company managers to be able to manage their company activities effectively and efficiently to achieve company goals in accordance with what has been set (Rahmawan, 2021). Waste is a big problem in the industrial world. One of them happened in a tissue industry in East Java. Where the production of towel tissue is one of the largest production items with total demand touching 16,000 tons in 2023. Competition between tissue product industry markets is increasingly competitive. The need for the use of tissue in everyday life is considered practical, there is what is known as facial tissue for facial care needs and towel tissue with high absorption is used for the needs of restrooms, kitchens and so on. Tissue is now considered a necessity for the community to have (Saputra et al., 2023). With this competition, it is necessary to increase productivity, one of which is by minimizing waste that occurs along the flow of the production process continuously, in order to run effectively and efficiently (Ramdani, 2021). In the towel tissue production process, there are various wastes that occur, based on observations identified as many as 32 types of waste. The waste starts from the distance between machines that are too wide so that the material transfer time becomes large, there is a large waiting time in the pope rell process, high rewinder machine setup time, large overproduction, and large product defects that force the company to rework. These various kinds of waste are very detrimental to the company in terms of time and cost, so improvements must be made immediately. The dominant approach method used to solve problems related to waste in the production process is Lean Manufacturing using Value Stream Mapping (VSM), Root Cause Analysis (RCA), and Seven Tools (Naufal & Rosyada, 2023). Waste generally consists of seven types, namely overproduction, waiting, motion, transportation, unnecessary process, inventory and defects (Novitasari & Iftadi, 2020).

Lean Manufacturing is an ongoing effort to eliminate waste that occurs in an industrial company and increase the added value of products (goods or services) to provide value to customers. Lean Manufacturing focuses on identifying and eliminating all forms of waste (Sulistiyowati et al., 2019). Lean Manufacturing starts by using a Value Stream Mapping approach. Value Stream Mapping (VSM) is the appropriate method. which can be used to identify, analyze waste, then find solutions to make proposed improvements to reduce waste that occurs (Komariah, 2022). Based on research that has been conducted by (Kurniawan & Hariastuti, 2020) The application of Lean Manufacturing with Value Stream Mapping (VSM) in the coating industry is significantly able to identify and eliminate waste 5 Non Value Aded (NVA) activities and shorten by 3.7% process lead time. Further research by (Suhardi et al., 2020) The application of Value Stream Mapping (VSM) in the SB45 Bra production process can reduce waste by decreasing production time and increasing efficiency by 6.17%.

Based on these problems, this study uses the Lean Manufacturing method with the Waste Assessment Model (WAM), where there are 6 respondents consisting of managers and production supervisors with qualifications to have at least 3 years of practical experience and are company functionalists based on research (Mayang et al., 2022), The Waste Assessment Model (WAM) method can be used to identify the types of critical waste that exist in the company (Krisnanti & Garside, 2022). Research by (Haekal, 2022) In the bottle printing industry, the Waste Assessment Model (WAM) method has succeeded in identifying critical waste that occurs in the production process, then with the Root Cause Analysis (RCA) and 5W + 1H methods to explore the root cause of the problem and provide recommendations for improvement, which has succeeded in increasing process efficiency and increasing total daily production. In this study, the process of identifying the cause of waste uses Root Cause Analysis (RCA) Tools with the 5 Why's method. This method is used to find out the root cause of existing waste (Novitasari & Iftadi, 2020). The results of the identification are used as a basis for planning recommendations for improving the production process using the 5W & 1H method. This research was conducted to identify and reduce waste that hampers productivity in the towel tissue production process, as well as provide suggestions for improvements to increase productivity to achieve effective and efficient processes and results.

RESEARCH METHOD

This research was carried out in the production of towel tissue located in East Java in January 2024 until the required data is sufficient. In this study, it is necessary to identify the variables that affect the occurrence of waste, the variable bound to this study is the waste crisis contained in the towel tissue production process and the independent variable is the relationship between waste in the production process with 7 wastes that will be observed in this study, namely Over Production, Inventory, Defect, Motion, Transportation, Over Processing, and Waiting. The research approach used is qualitative and quantitative, The use of both approaches is influenced by the use of the Waste Assessment Model (WAM) method in data processing, the Waste Assessment Model (WAM) method relies on inputs in the form of qualitative perceptions, then these qualitative values are converted into quantitative values so that they can be further processed using quantitative tools.

There are 3 methods used in data collection, namely observation for Value Stream Mapping (VSM), interviews for Root Cause Analysis (RCA), and improvement recommendations (5W1H), as well as questionnaire methods for the Waste Assessment Model (WAM). Based on the data collection carried out, there are two types of data obtained, namely Primary Data and Secondary Data. Primary data is data obtained through direct observation on the production floor, either through direct observation of objects or through interviews. The primary data in this study was carried out using several methods, namely direct observation, interviews, and questionnaire distribution. Furthermore, secondary data is information obtained through collecting data from other sources indirectly, by utilizing data that already exists in the office or company. Among them are a general description of the company, an overview of the production process and the number of machines, demand data and production quantities, and product defect data.

Data collection using time measurements for Value Stream Mapping (VSM) uses the stopwatch method so that data testing is required. Data testing is carried out, namely data adequacy testing is carried out to find out whether the processing time measurement data collected has met the required amount or not. In this research, the level of confidence used is 95% and the level of accuracy used is 5%, and the k value is 2. And data uniformity testing is carried out to determine whether the process time measurement data is within the control limits or not on the control chart. . The results of the mapping using Value Stream Mapping (VSM) are then calculated regarding the current Process Cycle Efficiency (PCE) before the repair and the future after the repair. This was done to compare conditions before and after repairs.

RESULT AND DISCUSSION

Identification of critical waste is carried out using the Waste Assessment Model (WAM) method. The questionnaire was carried out by creating Waste Assessment Model (WAM) questions, with the Waste Relationship Matrix Questionnaire, and the Waste Assessment Questionnaire based on research (Rawabdeh, 2005). Then it will be addressed to employees who understand the conditions of the towel tissue production process with qualifications has a minimum of 3 years practical experience and is a company functionalist based on research *(Mayang et al., 2022)*. So in this research the Waste Assessment Model questionnaire involved 6 respondents, namely 1 production manager, 3 tissue machine section supervisors, 1 stock preparation section supervisor, and 1 rewinder section supervisor. Next, for the root cause of the problem, analysis was carried out using Root Cause Analyst with the 5Whys tool based on critical waste from the Waste Assessment Model. Proposed improvements are carried out using the 5W1H method based on the results of the Root Cause Analyst. The root causes of waste are analyzed using the 5W1H method regarding the type of waste (What), where the source of waste is (Where), the person responsible (Who), when it occurs (When), the cause (Why) and then given suggestions for improvement (How).

The towel tissue production process starts from the machine setup process, where there are 3 sections, namely preparation stock, tissue machine, and rewinder, which runs with two lines in the preparation stock, running semi-automatically from the pulper to the rewinder, so that workers are positioned as managers of the production process via buttons to flow material from the puper to the chest machine, the rest from the chest machine to the Pope Rell is operated and monitored via Distributed Control System (DCS). An overview of the towel tissue production process flow is as described in Figure 2.

Current Value Stream Mapping

The towel tissue production process can be said to be a complex production process which uses 19 machines at once with a total of 59 activities, consisting of the machine setup process, operation process, chemical addition process, transfer process, until the product enters the finished good warehouse. A more detailed depiction of the towel tissue production process is mapped in current value stream mapping, where data collection is carried out directly, so data testing is required first, here are the results of the data testing (Table 1).

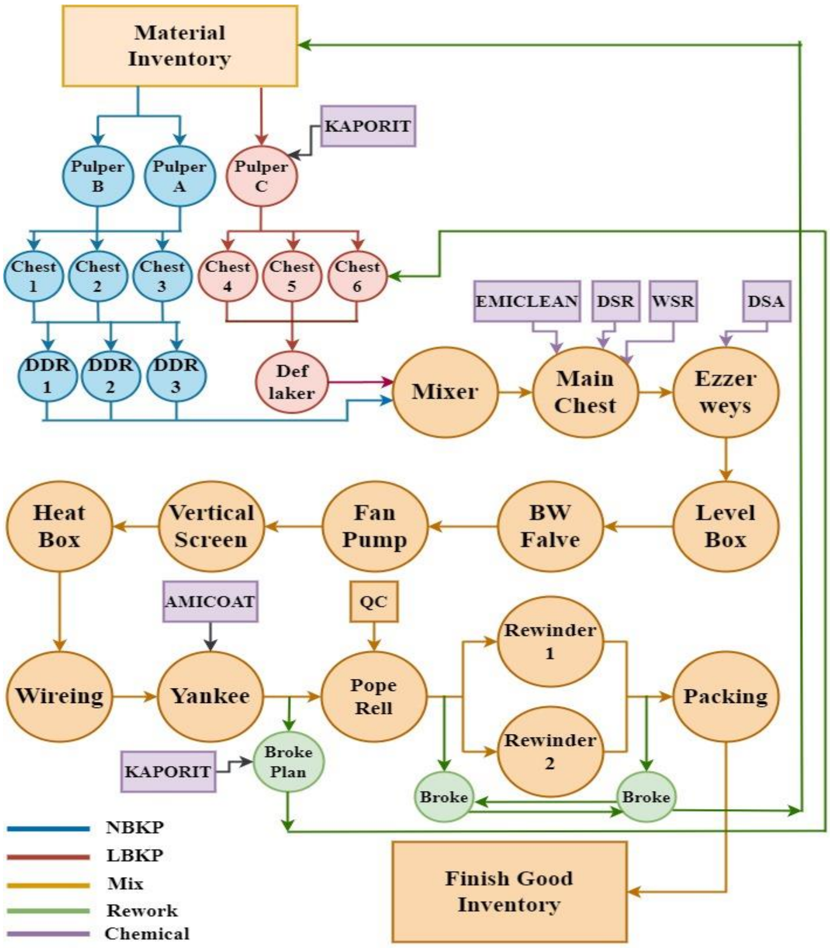

Figure 2. Towel tissue production process flow

Table 1. Machine Operation Data Adequacy Tests

No	Machine Name	∑x	∑x²	(∑x)²	N	N'	Inform.
1	Pulper (NBKP)	9.328	8.703.159	87.004.122	10	0,51	Enough
2	Pulper (LBKP)	12.271	15.061.263	150.582.349	10	0,32	Enough
3	Chest	7.874	6.199.578	61.992.002	10	0,10	Enough
4	DDR	590	34.843	348.100	10	1,53	Enough
5	Deflaker	596	35.489	354.620	10	1,21	Enough
6	Mixer	615	37.931	378.594	10	3,02	Enough
7	Main Chest	6.020	3.624.222	36.235.584	10	0,29	Enough
8	Ezzerweys	599	35.895	358.442	10	2,25	Enough
9	Level Box	642	41.375	412.549	10	4,67	Enough
10	BW Falve	672	45.298	451.853	10	3,98	Enough
11	Fan Pump	632	39.969	399.171	10	2,07	Enough
12	Vertical Screen	1.018	103.743	1.035.917	10	2,33	Enough
13	Headbox	7.459	5.563.813	55.636.681	10	0,04	Enough
14	Wearing	7.262	5.273.186	52.730.835	10	0,03	Enough
15	Yankee	8.693	7.557.117	75.563.033	10	0,17	Enough
16	Pope Rell	6.804	4.630.035	46.295.777	10	0,16	Enough
17	Rewinder	19.056	36.317.090	363.146.381	10	0,11	Enough
18	Packing	8.025	6.447.286	64.399.020	10	1,83	Enough
19	Broke Plan	14.542	21.148.262	211.455.222	10	0,21	Enough
20	Inspeksi	4.408	1.943.173	19.431.297	10	0,04	Enough
21	Elimination Defect Pope Rell	6.731	4.530.498	45.303.669	10	0,05	Enough

No	Machine Name	$\sum x$	$\sum x^2$	$(\sum x)^2$	N	N'	Inform.
22	Elimination Defect Rewinder	4.000	1.599.894	15.997.600	10	0,13	Enough
23	Elimination Overproduction From Roll	3.328	1.107.660	11.076.250	10	0,05	Enough

Table 2. Recapitulation of Machine Operation Data Adequacy Tests

No	Machine Name	Average	Std. Dev	BKA	BKB	Max	Min	Inform.
1	Pulper (NBKP)	932,8	17,5	967,7	897,8	957,9	908,8	Uniform
2	Pulper (LBKP)	1227,1	18,3	1263,8	1190,4	1253,1	1203,3	Uniform
3	Chest	787,4	6,5	800,3	774,4	796,9	779,2	Uniform
4	DDR	59,0	1,9	62,8	55,2	62,0	56,3	Uniform
5	Deflaker	59,6	1,7	63,0	56,1	62,2	57,2	Uniform
6	Mixer	61,5	2,8	67,2	55,9	66,5	57,9	Uniform
7	Main Chest	602,0	8,6	619,1	584,8	615,2	586,5	Uniform
8	Ezzerweys	59,9	2,4	64,6	55,1	64,2	57,4	Uniform
9	Level Box	64,2	3,7	71,5	56,9	68,5	58,9	Uniform
10	BW Falve	67,2	3,5	74,3	60,2	73,1	63,4	Uniform
11	Fan Pump	63,2	2,4	68,0	58,4	65,6	59,2	Uniform
12	Vertical Screen	101,8	4,1	110,0	93,6	106,8	96,3	Uniform
13	Headbox	745,9	4,0	753,9	737,9	751,8	741,0	Uniform
14	Wearing	726,2	3,4	732,9	719,4	732,1	722,8	Uniform
15	Yankee	869,3	9,5	888,3	850,3	883,3	854,3	Uniform
16	Pope Rell	680,4	7,1	694,7	666,1	690,3	671,5	Uniform
17	Rewinder	1905,6	16,5	1938,7	1872,6	1933,4	1884,2	Uniform
18	Packing	802,5	28,6	859,8	745,2	851,5	764,7	Uniform
19	Broke Plan	1454,2	17,4	1489,0	1419,3	1484,8	1434,1	Uniform
20	Inspeksi	440,8	2,2	445,2	436,4	443,6	437,6	Uniform
21	Elimination Defect Pope Rell	673,1	3,8	680,7	665,5	678,5	665,9	Uniform
22	Elimination Defect Rewinder	400,0	3,9	407,7	392,2	405,8	394,6	Uniform
23	Elimination Overproduction From Roll	332,8	2,0	336,8	328,9	335,5	329,4	Uniform

Based on the test results, the data is considered sufficient and uniform, because the data is within the upper control limit (BKA) and lower control limit (BKB). So it can be used in data processing in research. Next, create a current value stream mapping which is preceded by calculating machine setup, operation and transfer times, machine scrap data, uptime calculations, Work in process (WIP), and the capacity of each process. Based on these results, current value stream mapping (CVSM) can be mapped. Based on this mapping, it can be seen that the total lead time is 23,261.66 seconds, with value added (VA) activities of 10,529.29 seconds, Non Value Added (NVA) of 3,069.61 seconds, Necessary Non Value Added (NNVA) of 9,662 .76 seconds. So that the Process Cycle Efficiency Current calculation can be carried out for the towel tissue production process (without involving rework sections as follows) as follows:

$$Current\ PCE = \frac{Value\ Added\ Time\ (VA)}{Total\ Lead\ Time} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)$$

$$= \frac{10.529,29}{23.261,66} \times 100\% = 45,26\%$$

Critical waste analysis with the Waste Assessment Model (WAM)

At the data processing stage, waste identification is carried out, namely by using the Waste Assessment Model (WAM), where the Waste Assessment Model (WAM) consists of 2 methods that will be used, namely the first is the Waste Relationship Matrix (WRM) method and the second is the Waste Relationship Matrix (WRM) method. Waste Assessment Questionnaire (WAQ). Where is the Waste Relationship Matrix (WRM) to identify the relationship between types of waste, as well as the Waste Assessment Questionnaire (WAQ) to determine the most dominant waste and the levels between waste. After recapitulating the questionnaire results, the Waste Relationship Matrix (WRM) letter symbols are then converted into numerical weights in accordance with the predetermined provisions, namely letter A = 10, letter E = 8, letter I = 6, letter O = 4, letter U = 2 and the letter X = 0. The conversion of Waste Relationship Matrix (WRM) letter symbols into numerical weight form can be seen in the following table:

Table 3. Waste Relationship Matrix Value

F/T	O	I	D	M	T	P	W
O	**10**	8	6	10	10	0	6
I	6	**10**	8	4	6	0	0
D	6	8	**10**	4	8	0	8
M	0	6	8	**10**	0	8	8
T	4	4	8	10	**10**	0	6
P	10	8	6	6	0	**10**	8
W	2	6	8	0	0	0	**10**

Table 4. Recapitulation of Score Calculation and Waste Percentage

F/T	O	I	D	M	T	P	W	Score	Persentase (%)
O	**10**	8	6	10	10	0	6	50	17,61
I	6	**10**	8	4	6	0	0	34	11,97
D	6	8	**10**	4	8	0	8	44	15,49
M	0	6	8	**10**	0	8	8	40	14,08
T	4	4	8	10	**10**	0	6	42	14,79
P	10	8	6	6	0	**10**	8	48	16,90
W	2	6	8	0	0	0	**10**	26	9,15
Score	38	50	54	44	34	18	46	**284**	
Persentase (%)	13,38	17,61	19,01	15,49	11,97	6,34	16,20		**100**

Based on the table above, it is known that the value of the line from Overproduction (O) has the largest score and percentage, namely 17.61%. This percentage shows that waste overproduction, if it occurs, will have a significant influence on the emergence of other waste. Meanwhile, in the matrix column, it is also known that the value of to Defect (D) has the largest score and percentage, namely 19.01%. This percentage shows that Defect waste is the waste that is most influenced by other waste.

Next, the results of the Waste Relationship Matrix (WRM) are included in the Waste Assessment Questionnaire (WAQ) calculation. The data used in this weighting comes from the Waste Assessment Questionnaire (WAQ) questionnaire data consisting of 68 different questions, where each questionnaire question presents an activity, condition or characteristic that might cause certain waste. The Waste Assessment Questionnaire (WAQ) questionnaire is divided into two types of question groups, namely "from" and "to". The results of the questionnaires from the 6 respondents were averaged, then the average results were included in the calculation of the Waste Assessment Questionnaire (WAQ), so that the following results were obtained:

Table 5. Recap of Final Yj WAQ Calculation Results

	O	I	D	M	T	P	W
Score (Yj)	0,54	0,48	0,47	0,48	0,53	0,52	0,41
Pj factor	235,57	210,77	294,58	218,21	177,05	107,12	148,28
Yj Final	127,01	102,05	138,71	104,51	94,25	55,20	61,38
% Yj Final	18,59	14,94	20,31	15,30	13,80	8,08	8,99
Rank	2	4	1	3	5	7	6

Based on the recapitulation results above, it can be concluded that the largest waste occurs in the towel tissue production process is caused by waste defects with a percentage of 20.31%, then the second largest waste is overproduction at 18.59%, then the third largest waste is Motion at 15.30%, then the fourth largest waste is Inventory at 14.94%, next The fifth largest waste is Transportation at 13.80%, then the sixth largest waste is Waiting at 8.99%, and the seventh largest waste is excess Process at 8.08%

Analyze the root of the problem with Root Cause Analysis (RCA)

Analysis of the root cause of this problem was carried out using the Root Cause Analysis (RCA) Tools with the 5 Why's method, where this method makes it possible to explore the root cause of the problem with 5 Why's. This Root Cause Analysis (RCA) was created based on the critical waste ranking results from the Waste Assessment Model (WAM), as well as direct observation in the field and interviews with managers, supervisors and production operators. The results of the Root Cause Analysis for waste of waiting were as follows:

Table 6. Identifies 5 Whys waste of defect

Waste	Sub Waste	Why 1	Why 2	Why 3	Why 4	Why 5
Defect	Tangled	The chemical coating shower was clogged so that the yankee was not coated evenly, and the drying and release process was not perfect	The shower is clogged by chemical materials and microorganisms that grow on the rim of the shower	Screening filter for perforated chemical filtration	Lack of maintenance on shower machines and filter screening, including checking every hole	There is no SOP for checking each shower hole when maintenance is carried out
	Wrinkles	Yankees Less Hot	Insufficient Boiler Capacity	There are changes in environmental air temperature. Extreme weather such as very cold temperatures can increase heat demand and exceed boiler capacity.	Delay in the boiler system responding to changes in air temperature.	There was a leak in the boiler pipe which was not immediately discovered before the production process.
		Operators are late in responding to worn Coating Release	Replacement of lining removal is based on operator estimation and experience	There are no visible indicators to know if the release layer has worn out	The Yankee engine used is an old engine and has not been upgraded regarding the installation of sensors and indicators	
	Hole (Perforated)	Coating the yankee crust	Dusty environmental conditions will stick and cause crusts on the Yankee layer	There is no casing on the yangkee layer so that foreign objects such as dust can enter	The Yankee engine used is an old engine and has not been upgraded regarding the installation of the Yankee casing	

Recommended Alternative Improvements (5W1H)

Based on the root of the problem, several recommendations for improvement with 5W1H are obtained as follows:

Table 7. Recommendations For Improving Waste Of Defects

What	Where	Who	When	Why	How
Crumpled Tissue	Yankee Machine Chemical Shower	DCS Operator	When drying the tissue	Lack of maintenance on shower machines and filter screening, including checking every hole	Make regular maintenance schedules, including clear SOP for checking and cleaning shower coats, followed by monitoring and evaluating implementation.
Wrinkles	Yankee Engine Shell Dryer	DCS Operator	When drying the tissue	Delay in the boiler system responding to changes in air temperature.	Carry out regular boiler performance checks and install leak alarms.
	Doctor Blade Yankee Machine			There are no visible indicators to know if the release layer has worn out	Installing sensors and indicators of doctor blade wear, as well as establishing SOPs for when to replace the doctor blade
Holes	Yankee Engine Shell Dryer	DCS Operator	While drying the tissue	There is no casing on the Yankee coating so that foreign objects such as dust can enter	Maintaining the cleanliness of the environment around the engine, consideration for upgrading the new engine, as well as installing casing for the Yankee engine coating

Based on the analysis of the 5W1H method which identifies waste with 6 questions, recommendations for improvement for crumpled tissue waste were obtained, namely making regular maintenance scheduling, including clear SOPs for checking and cleaning shower coatings, followed by monitoring and evaluating its implementation. Furthermore, wrinkled tissue can be resolved by carrying out regular boiler performance checks, and installing leak alarms, as well as installing sensors and wear doctor blade indicators, as well as setting an SOP for when to replace the doctor blade. As well as defect holes, namely by maintaining the cleanliness of the environment around the engine, consideration for upgrading the new engine, as well as installing casing for the Yankee engine coating.

Future Value Stream Mapping

Once the various existing wastes are known, the root causes of the problem, as well as alternative recommendations for making improvements, can be mapped in Future Value Stream Mapping (FVSM). So that a comparison of conditions before and after the implementation of improvements can be obtained, where we can see various improvements in process improvements starting from Non Value Added (NVA) and Necessary Value Added (NNVA) which show a decrease, as well as the total time and value of Process Cycle Efficiency (PCE) which significantly receives a positive impact of the improvements that have been made. A recapitulation of the comparison before and after repairs is as follows:

Table 8. Recapitulation Table Comparison of Results Before and After Improvement

Category	Current	Future	Percentage
VA (Detik)	10.529,29	10.529,29	0
NVA (Detik)	3.069,61	283,58	90,76
NNVA (Detik)	9.662,76	5.543,16	42,63
Total Lead Time (Detik)	23.261,66	16.356,02	29,69
Process Cycle Efficiency (%)	**45,26 %**	**64,38 %**	-

The results of this data processing show that the use of the Value Stream Mapping (VSM), Waste Assessment Model (WAM), Root Cause Analysis (RCA), and recommendations for improvements using 5W1H, was successful in increasing process efficiency. The results of identifying critical waste using the Waste Assessment Model (WAM) method also show success in identifying critical waste where the three largest critical wastes that occur in the towel tissue production process are waste defects at 20.31%, then overproduction at 18.59%, and Motion amounting to 15.30%. The results of the Waste Relationship Matrix (WRM) also show that each waste is related to one another (dependent), where from Overproduction is 17.61%, waste from process is 16.90%, and waste from defects is 15.49%. These three wastes are sequentially the waste that has the biggest influence on the creation of other waste, and the waste that receives the biggest impact is the creation of waste to defects of 19.01%, waste to Inventory of 17.61%, and in third position is waste to waiting was 16.20%. Based on these results, the source of the waste problem can be identified and the consequences it has for the emergence of other waste. These results are in line with previous research conducted by (Kuncoro, 2023) using the Waste Assessment Model (WAM) method, where in the plywood production process the critical waste that occurred was successfully identified, namely defects, inventory and overproduction.

The mapping results in the Future Value Stream Mapping in the attachment show quite significant changes, where the total lead time which was previously 23,261.66 seconds, decreased by 29.69% to 16,356.02 seconds, with an activity value added (VA) of 10,529.29 seconds is the same as the condition after improvement, namely 10,529.29 seconds, Non Value Added activity (NVA) which was previously 3,069.61 seconds was reduced by 90.75% to 283.58 seconds, and Necessary Non Value Added activity (NNVA) was 9,662, 76 seconds, reduced by 42.63% to 5,543.16 seconds. These results are in accordance with research conducted by (Satria & Yuliawati, 2018) which also uses the Value Stream Mapping (VSM), Waste Assessment Model (WAM) method where the total time previously 20,255.4 seconds was reduced to 14,767.40 seconds, with a value added (VA) activity of 7,924.4 seconds and the same as after the improvement was 7,924.40 seconds, Non Value Added (NVA) activity which was previously 5,488 seconds was reduced to 0 seconds, and Necessary Non Value Added (NNVA) activity was 6,843 seconds, the same as after the improvement to 6,843 seconds.

Recommended improvements that have succeeded in supporting this are the setup time by 50% from 5341.96 seconds to 2670.98 seconds. This reduction in setup time is the result of routine and structured maintenance, as well as installation and repair of devices that help with setup time efficiency, such as indicators, sensors, and so on. Furthermore, the reduction in rewinder machine setup time resulted from upgrading the machine with a setup automation system, saving time from the setup process, namely 80% from the original 1810.78 seconds to 362.156 seconds. This also has the impact of no waiting material activity because the setup process has been accelerated. implementation of facilities to support the process of eliminating product defects in the process from the Pope Rell machine, namely the electric textile cutter, the time used was reduced by 80%, from 673.08 seconds to 134.616 seconds. Likewise what happened in the process of eliminating product defects on the rewinder machine, which was reduced by 80% from 399.97 seconds to 79.994 seconds, the process of eliminating overproduced products was reduced by 80% from 344.83 seconds to 68.966 seconds. And the transfer time for the overproduced product, which was previously transferred from the rewinder to the pope rail for elimination, can now be eliminated directly in the rewinder machine, so that the previous time of 332.81 seconds becomes 0 seconds because this capacity is eliminated. Furthermore, the final results of this research obtained a Process Cycle Efficiency (PCE) of 64.38%. These results show conformity with research by (Novitasari & Iftadi, 2020) where process improvements in accordance with root analysis were able to streamline the Door PU line B process with changes in the number of activities able to increase the PCE value from 23.67% to 31.45%.

CONCLUSION

The results of observations, interviews and then calculations and analysis using the Waste Assessment Model (WAM) method with three main stages show that the largest critical waste that occurs in the towel tissue production process is waste defect at 20.31%, then overproduction at 18.59%, Motion of 15.30%, Inventory of 14.94%, Transportation of 13.80%, Waiting of 8.99%, and Process waste in last position with 8.08%. The Root Cause Analysis (RCA) method finds the root causes of waste such as defects, overproduction and motion. Waste of defects, with 14 subwastes, is caused by yankee scale, clogged showers, and human error. Waste of overproduction, with 2 subwastes, occurs due to management policies and low operator awareness. Waste of motion, with 4 subwastes, is caused by manual transfer processes and lack of supporting facilities. The results of the Root Cause Analysis (RCA) analysis are used to provide recommendations for improvements using the 5W1H method. The recommendations include developing maintenance SOPs, implementing a FIFO (First In First Out) system, and adding facilities such as mini drills and vacuums to simplify the process. Cooperation in applying digital technology is also emphasized. In Future Value Stream Mapping (VSM), the results of implementing improvements were obtained, namely that the total lead time, which was previously 23,261.66 seconds, was reduced by 29.69% to 16,356.02 seconds, with activity value added (VA) of 10,529.29 seconds, the same as the condition after improvements, namely 10,529.29 seconds, Non Value Added (NVA) activity which was previously 3,069.61 seconds was reduced by 90.75% to 283.58 seconds, and Necessary Non Value Added (NNVA) activity was 9,662.76 seconds, reduced by 42.63% to 5,543.16 seconds. As for the final results of Future PCE, the Process Cycle Efficiency value was obtained after improvements, where there was an increase in efficiency of 19.12% from 45.26% to 64.38%.

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