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Lean-Practices in The Metallography CRM Laboratory to Support Industry 4.0 in Manufacturing

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ABSTRACT:*Based on the data obtained, 169 metallographic samples are out of the target test timeliness because there is waste in the specimen preparation process until reporting the results. The purpose of this study is to identify the types of waste, identify the types of waste that often occur, and provide recommendations for improvements to reduce waste in the lab. Metallography CRM. This research uses the lean manufacturing approach method by knowing the most dominant type of waste using the 7waste questionnaire and obtaining the final percentage value for each waste so that the Value Stream Mapping Tools (VALSAT) used are Process Activity Mapping (PAM). At the improvement recommendation stage, a Pareto diagram is used to determine the most dominant waste. Fishbone diagram to find out the root cause of the waste problem, then the Process Activity Mapping (PAM) method is used to suggest improvements, and the 5W+1H method to plan improvements in the form of making standard standards in detecting prospective samples in Work In Process (WIP) status, automating the reporting process, calculating the frequency of use of each supporting material, providing used plates and cutting pliers, creating training programs, making requests for repair of wind taps, moving emery storage, creating inspection forms, and making standard standards to determine the number of samples in one mounting. This research resulted in an overall process time efficiency of 12%, from 202 minutes to 178 minutes. Value Added (VA) activities remained the same at 18 activities with a total time of 107.2 minutes, while Necessary Non-Value Added/Non-Value Added (NNVA/NVA) activities decreased from 40 activities to 35 activities with a total time from 94.8 minutes to 70.8 minutes. With the combination of these two systems, the optimization targets of lean and digital manufacturing have attracted attention to research new improvement approaches in future production systems.*

KEYWORDS *7 Waste, Value Stream Analysis Tools (VALSAT), Process Activity Mapping (PAM), Fishbone Diagram, 5W+1H.*

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I. INTRODUCTION

The implementation of Industry 4.0 is one of the major projects in Presidential Regulation No. 18 of 2020 concerning the 2020-2024 Medium-Term Development Plan (RPJMN) [1]. The implementation of Industry 4.0 is an opportunity to revitalize the manufacturing sector in the country to be more efficient and produce quality products. Therefore, the government as a policymaker will continue to encourage and facilitate the real needs of priority sectors in adopting industry 4.0 technology optimally [2]. Industry 4.0 promises increased productivity and flexibility for the manufacturing industry, which translates into greater customer value and lower costs [3], [4]. Lean manufacturing has long promoted principles and tools that focus on value-adding activities, waste elimination, and continuous improvement [5]. Even the most successful lean manufacturing companies, in terms of efficiency and quality achieved through waste reduction, will admit that there are still many opportunities for improvement.

The 4th industrial revolution also known as industrial internet, smart manufacturing, smart factory, and integrated industry, is at the forefront of improvements relating to higher flexibility and adaptability of production systems [6]. The goals of Industry 4.0 are in line with the objectives of reducing lead times and costs, continuously improving productivity, and enabling continuous improvement cycles [7]. Industry 4.0 technology is considered a strategy to make manufacturing processes more efficient while improving product quality, but the process of integrating technology into existing production systems and processes that can be supported by technology continues to evolve to increase productivity and flexibility [8]. With the combination of these two systems, the optimization targets of lean and digital manufacturing have attracted attention to research new improvement approaches in upcoming production systems.

The CRM Metallurgy Laboratory is a laboratory with the main function as a support unit for the Cold Rolling Mill (CRM) concerning the control of the production process parameters of raw materials and the final product of Cold Rolled Coil (CRC). In the CRM metallurgical laboratory, there are 3 types of laboratories, namely the mechanical lab for testing the mechanical properties of CRC, the metallographic lab which functions to analyze the microstructure of CRC, and the chemical lab to control production process parameters. The CRM metallurgical laboratory has a target test accuracy time (number of test days) which is calculated from the entry of the sample until the reporting of the test results is completed.

The target accuracy of the test time is 2 days, but in 2023 there were test times that did not reach the target. The processing time of more than 2 days is grouped according to the end or final application of CRC products which include frame housing & general purpose, pipe & tube, enamelware, and automotive body & parts. There were 60 samples for the frame housing & general-purpose end-user that took more than 2 days, 169 samples for the pipe & tube end-use, 0 samples for the enamelware end-use, and 55 samples for the automotive body & parts end-use. From this data, it can be seen that end-use pipes & tubes have the highest total number of samples whose processing time is out of target. The testing process is declared complete when all test items have been carried out and the results have been entered into the LIMS (Laboratory Information Management System) application. For end-use pipe & tube, there are 4 test items, namely hardness testing, tensile testing, bend testing, and metallographic analysis. Each test item has a total time of 15.7 minutes per sample for hardness testing, 11.3 minutes per sample for tensile testing, 5.5 minutes per sample for bend testing, and 202 minutes per sample for grain size and shape analysis. Based on this data, the longest total test item time on CRC products with pipe & tube enduses is the large and grain shape test located at the CRM Metallography Laboratory location with a total time of 202 minutes. The most influential factor in not achieving the target test time is the process in the CRM Metallography Laboratory.

This research aims to identify the types of waste that often occur and provide recommendations for improvements to reduce waste in the lab. Metallography CRM as part of efforts to support Industry 4.0 in manufacturing.

The concept of lean manufacturing is more suitable to be applied to this research. This is because Lean practice requires defective product data, while in the lab. CRM metallography does not have data on product defects. Defects that exist in the lab. CRM Metallography is a defect of specimens caused by an inappropriate preparation process and these defects can still be directly repaired so the defect data collection process is difficult to do. To reduce the waste that occurs in the CRM metallography laboratory, the steps taken are to identify each activity that is included in both non-valueadded and value-added, then make an effective improvement design to reduce or even eliminate the waste. According to [9], one of the approaches used to reduce or eliminate waste is lean manufacturing using the Value Stream Mapping method. By using this method, it is expected that the CRM metallography lab can achieve the target testing time of a maximum of 2 working days.

The combination of Technology 4.0 and lean practice principles provides benefits from both paradigms showing improvements in time and productivity in several companies in Morocco [10]. Lean principles in healthcare improve the quality and cost of services with the result that lean provides a flexible set of skills that can be introduced and applied in different pharmacy instructional settings [11]. The implementation of lean practices also increases innovation in small and medium enterprises so policymakers need to understand the heterogeneity of innovators in SMEs and how they innovate differently, the development of external and internal activities [12]. Lean approaches and practices in public services and higher education with a focus on eliminating waste can be applied in every organization with the result of a proposed waste management framework to provide orientation to managers and academic and university services about waste [13]. The development of lean practices in the field of projects is the application of Lean Product Development (LPD) to develop items that are technically complex and have substantial uncertainty about the outcome of the product with longer development costs with proposed research results and recommendations to overcome the problem [14].

II. RESEARCH METHODS

a. Lean Manufacturing

Lean manufacturing, a system that strives for continuous improvement and workforce integration with a clear focus on value-adding activities and elimination of waste, has been widely recognized and accepted in manufacturing [15], [16].

Fig 1. 7 Waste

b. 7 Waste

The basic principle of lean manufacturing is to eliminate waste. According to [17], The 7 wastes include waste of transportation, waste of inventory, waste of motion, waste of delay (waiting), waste of overproduction, waste of overprocessing, and waste of defects [18]. 7 Waste in **Fig 1.**

c. Value Stream Mapping

Value Stream Mapping (VSM) is a method used to create a production flow map [19]. All activities, both value-added and non-value-added, that are used to produce a product through a process flow are called value streams [20].

d. Value Stream Analysis Tools (VALSAT)

According to [21], VALSAT is a tool to select the appropriate detailed mapping to identify the biggest waste in the company. The purpose of using detailed mapping is to map the waste that occurs in the value stream process [22].

e. Process Activity Mapping (PAM)

PAM serves to identify lead time and productivity in both physical product flow and information flow [23].

f. Industry 4.0

Industry 4.0 is a strategic program to develop an advanced production system to improve the productivity and efficiency of the national industry [24]. It is the integration of a series of new and convergent technologies that add value to the entire product life cycle [25], [26]. The product life cycle of Industry 4.0 is in **Fig 2.**

Fig 2. The product life cycle of Industry 4.0 [27]

g. Research Framework

Research framework in Fig 3.

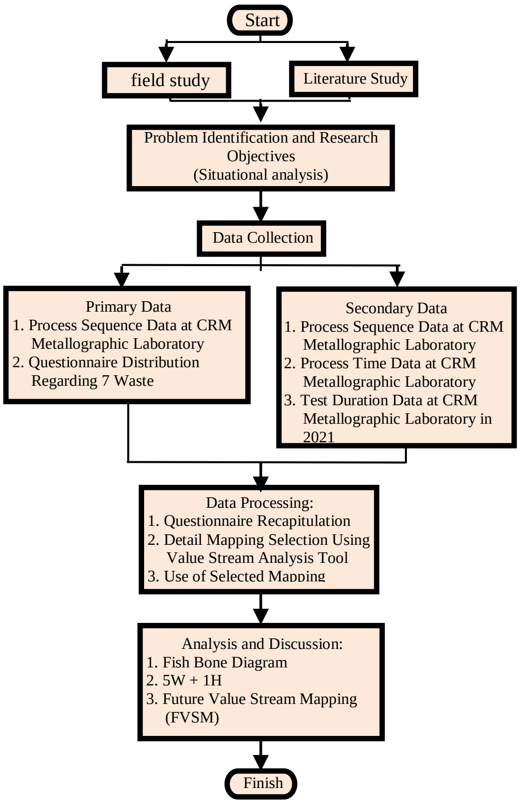

Fig 3. Research framework

This research starts from a field study conducted through direct observation of the work process in the cold rolling mill area and CRM Metallography laboratory and downloading sample data in 2022. Literature study through journals, books, and articles related to lean manufacturing to identify existing problems in the CRM metallographic laboratory and the research objectives to be achieved. To achieve the objectives of this research, data collection is carried out both primary and secondary data. Primary data is data that is directly taken through direct observation such as process sequence data in the CRM metallographic laboratory and the results of distributing related questionnaires. Secondary data is data obtained from secondary sources such as company documents that follow the research topics to be discussed. Examples of these documents are laboratory quality objectives for 2022, time data starting from the preparation process to reporting metallographic analysis results, and test duration data in the CRM metallographic laboratory. From a set of data that has been obtained, data processing is then carried out such as recapitulating questionnaires regarding 7 wastes, selecting mapping details using the Value Stream Analysis Tool (VALSAT), and using selected mapping details. The results of the data processing are then analyzed using fishbone diagrams and 5W + 1H so that recommendations and improvement plans can be obtained to reduce waste in the CRM metallographic laboratory. The distribution of the 7 waste questionnaires was carried out to identify waste in the CRM metallographic laboratory. The questionnaire was addressed to 6 respondents who knew in detail about the existing processes in the CRM metallographic laboratory, namely the CRM Metallurgical Lab Engineer, Analyst Group A, B, C, and D, and Non-Shift Laboratories

III. RESULTS AND DISCUSSION

The metallographic specimen preparation process is carried out in 2 areas, namely the lab preparation area. Metallurgy CRM and lab area. CRM Metallography lab area Process flow of metallographic specimens in **Fig 4**

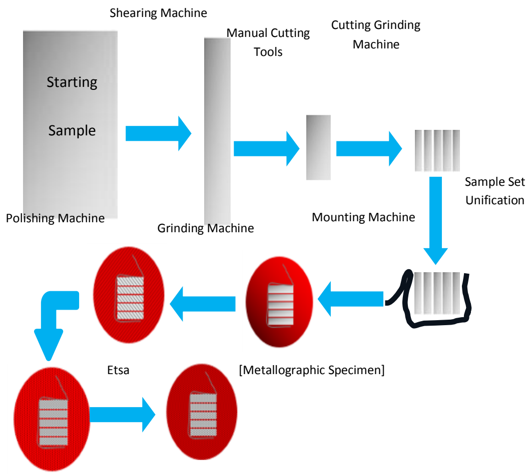

Fig 4. Process flow of metallographic specimens

The results of the recapitulation of the waste questionnaire in the CRM Metallurgy Laboratory are in **Table 1**.

Table 1. Recapitulation of 7 waste questionnaires

No	Wastage results	Value Weight						Total	Mean	Rank
		A	B	C	D	E	F			
1	Over Production	0	0	0	1	1	0	2	0,33	7
2	Defect	2	1	1	1	0	1	6	1	4
3	Inventory	0	2	0	1	0	0	3	0,5	6
4	Overproduction	3	1	0	1	0	0	7	1,17	3
5	Transportation	1	1	1	1	0	0	4	0,67	5
6	Waiting	4	4	4	1	3	4	20	3,33	1
7	Motion Waste	4	3	3	1	3	3	17	2,83	2

Description:
A = CRM Metallurgical Lab Engineer
B = Analyst GroupA
C = Analyst Group B
D = Analyst Group C
E = Analyst Group D
F = Non-Shift Laborer

Based on Table 1. The percentage value of waste from largest to smallest is waiting by 34%, motion by 0.29, over-processing by 0.12, defects by 0.10, transportation by 0.07, inventory by 0.05, and overproduction by 0.03. From this data, a Pareto diagram is in **Fig 4.**

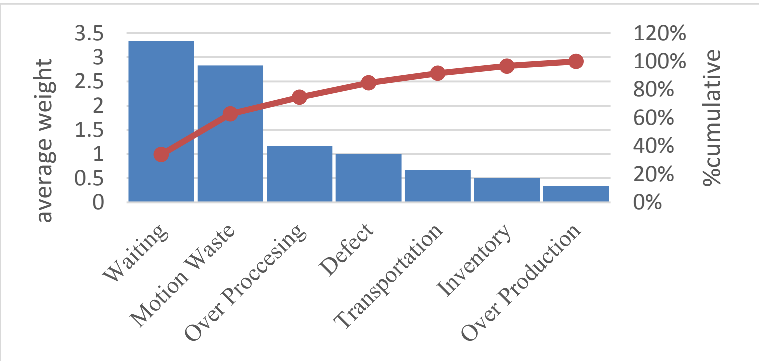

Fig 4. Pareto Diagram of 7 waste in the metallography laboratory of CRM

From the results of the questionnaire that has been obtained, the next step is to create a tools selection matrix using VALSAT (Value Stream Analysis Tools). The selected tools will be used to identify waste that occurs in the CRM metallographic laboratory. VALSAT calculation in which there is a relationship between the seven tools and the seven wastes. The results of the relationship are used to select the right tools to map waste. The VALSAT methods are in **Table 2**.

Table 2. CRM metallographic laboratory value stream analysis tool (VALSAT)

Waste	Mean	Mapping Tools						
		Process Activity Mapping	Supply Chain Response Matrix	Production Variety Funnel	Quality Filter Mapping	Demand Amplification Mapping	Decision Point Analysis	Physical Structure (a) Volume (b)Value
Over Production	0,3	L 0,3	M 1,0		L 0,3	M 1,0	M 1,0	
Time Waiting	3,3	H 30,0	H 30,0	L 3,3		M 10,0	M 10,0	
Transport	0,7	H 6,0						L 0,7
Inappropriate Processing	1,2	H 10,5		M 3,5	L 1,2		L 1,2	
Unnecessary Inventory	0,5	M 1,5	H 4,5	M 1,5		H 4,5	M 1,5	L 0,5
Unnecessary Motion	2,8	H 25,5	L 2,8					
Production Defect	1,0	L 1,0			H 9,0			
Amount		74,8	38,3	8,3	10,5	15,5	13,7	1,2
Rank		1	2	6	5	3	4	7

Description:
H = High correlation and usefulness (Multiplier factor = 9)
M = Medium correlation and usability (Multiplier Factor = 3)
L = Low correlation and usability (Multiplier factor = 1)

The next step is to rank the tools from highest to lowest. The tool that has the highest weight will be selected to identify waste in the CRM metallographic laboratory. A recapitulation of the VALSAT results in **Table 3**.

Table 3. Value stream mapping tools (VALSAT)

No	Detailed Mapping Tools	Score	Rank
1	Process Activity Mapping	74,83	1
2	Supply Chain Response Matrix	38,33	2
3	Demand Amplification Mapping	15,50	3
4	Decision Point Analysis	13,67	4
5	Quality Filter Mapping	10,50	5
6	Production Variety Funnel	8,33	6
7	Physical Structure (a)volume (b)value	1,17	7

Based on the VALSAT recapitulation calculation in Table 3, it can be seen that the selected tool is process activity mapping (PAM). This tool was selected because it received the first rank with a total weight of 74.83.

a. Process Activity Mapping (PAM) - Current Value Stream Mapping

Process Activity Mapping (PAM) is a tool used to map all activities so that waste in the CRM metallographic laboratory can be minimized. The results of the PAM calculation are then recapitulated to facilitate the analysis process. A recapitulation of the total operating time, transportation, storage, and delay is in **Table 4**.

Table 4. Activity time

Activity	Amount	Total Time (minutes)	Percentage of time
Operation	38	164	81
Transportation	8	13	6
Inspection	1	5	2
Storage	1	4	2
Delay	10	16	8
Total	58	202	100

Based on **Table 4**, the activity that has the largest number of activities is an operation of 38 activities with a total time of 164 minutes and a percentage of time reaching 81%. Then there is transportation which has 8 activities with a total time of 13 minutes and a percentage of time of 6%, inspection has 1 activity whose total time is 5 minutes with a percentage of time reaching 2%, storage has 1 activity that lasts 4 minutes with a percentage of time of 2%, and delay has 10 types of activities that take 16 minutes with a percentage of time of 8%. After finding the number of activities and time, the next step is to group the types of activities into VA, NNVA, and NVA categories in **Table 5**.

Table 5. Activity category time

Activity	Amount	Total Time (Minutes)	Percentage
VA	18	107,2	53
NNVA	20	61,8	31
NVA	20	33	16
Total	58	202	100

Based on **Table 5**. value-added activities (VA) have 18 types of activities that have a total time of 107.2 minutes and a percentage of time of 53% which indicates that most of the activities have added value. Types of non-value added but necessary activities amounted to 20 activities with a total time of 61.8 minutes and a percentage of time of 31%, and non-valueadded activities (NVA) had a total of 20 types of activities with a total time of 33 minutes (16%).

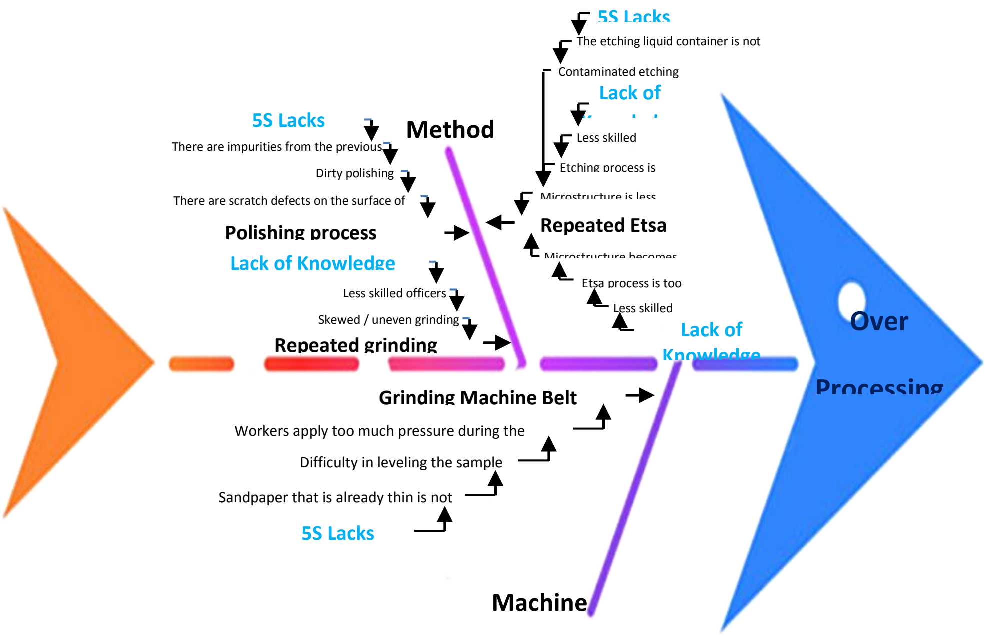

Fig 5. Fishbone diagram of over-processing

b. Recommendation for Improvement

Improvement recommendations for 7 wastes are taken from the results of fishbone diagram analysis and process activity mapping analysis. The results of the process activity mapping analysis are the basis for making future state mapping. Fishbone diagrams are used to find the causes of existing problems in the CRM metallographic laboratory related to the process of preparing, analyzing, and reporting the results of analyzing the size and shape of the grains of cold-rolled steel products based on 4 factors, namely, humans, methods, machines, and materials. Based on the Pareto diagram in **Fig** 4, 4 wastes often occur, including waiting, motion, over-processing, and defects. The fishbone diagram for waste over-processing is in **Fig 5.**

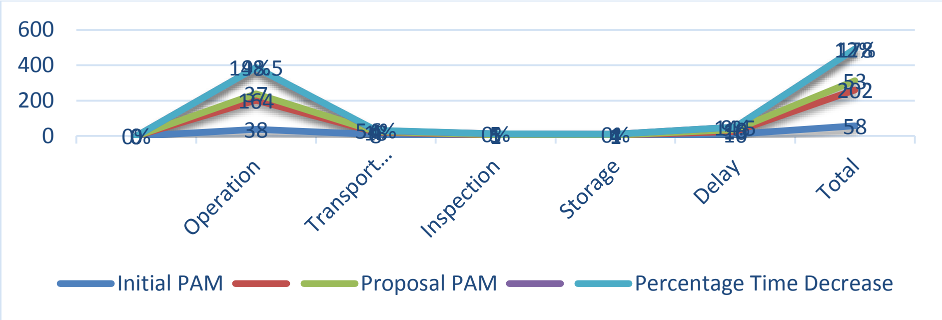

Fig 6. Comparison of initial PAM with proposed PAM

Improvements Based on Process Activity Mapping (PAM)

Based on the proposed PAM, several activities are proposed to be improved or eliminated, namely in the process of uniting samples, grinding, polishing, etching, and preparation of reporting results. The results of the proposed PAM calculation are then recapitulated and compared to the initial PAM recapitulation. Comparison between the initial PAM and the proposed PAM based on total operating time, transportation, storage, and delay in **Fig 6.**

In value added activities (VA) there is no decrease in both the number of activities and the total time required. Non-value added necessary activities (NNVA) The number of activities did not decrease, but there was a decrease in total time from 61.8 minutes to 46.8 minutes so the percentage of time reduction was 24%. For non-value added activities (NVA) there was a decrease in activity from 20 to 15 activities with a decrease in total time from 33 to 24 minutes so a percentage reduction in time was obtained of 27%. Overall, the process in the CRM metallographic laboratory from the preparation process to the reporting of results has decreased from 58 activities to 53 activities with a total time from 202 to 178 minutes so that the percentage of time reduction is 12%. The results of activity category time are in **Fig 7.**

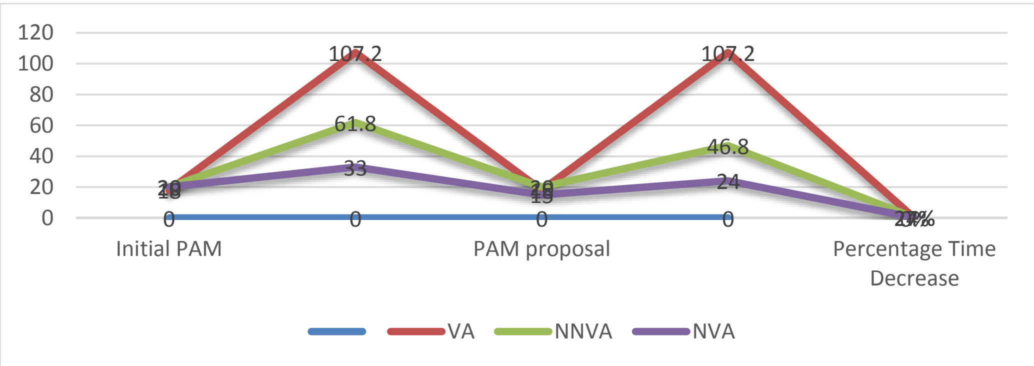

Fig 7. Activity category time

After the root cause of each waste is found and the proposed PAM is completed, the next step is to plan improvements using the 5W + 1H in **Table 6.**Based on improvements from the fishbone diagram, proposed PAM, and 5W + 1 H analysis, the future state mapping in **Fig 8.**

Table 6. 5W+1H

No	Problem	Why	What	Where	When	Who	How
1	There is no standard for detecting coil work-in-process (WIP) with metallographic samples.	Reduce waiting waste	Create a standardized standard	Lab. CRM Metallurgy	August - September 2023	Engineer	Discuss with Production Planning Control (PPC) & Work In Process (WIP), create and socialize standard standards.
2	No automation in sample identity copying	Reduce waiting waste	Automate the copying of sample data	Lab. CRM Metallurgy	September 2023	Engineer & Analyst	Create a report file inExcel form that contains a certain formula
3	The arrival lead time for each material is different	Reduce waiting waste	Calculate the safety stock of each material	Lab. CRM Metallurgy	August 2022 - August 2023	Engineer & Analyst	Calculate usage frequency, arrival lead time, safety stock, and Reorder Point (ROP) of each supporting raw material.
4	There is no optimal way to integrate the samples	Reduce waiting & motion waste	Changing the sample pooling method	Lab. CRM Metallurgy	August 2023	Analyst	Make scrap plate inventory & place cutting pliers in the lab. Metallography
5	Lack of knowledge transfer	Reduce movement, over-processing, and defect waste	Carry out knowledge transfer effectively	Lab. CRM Metallurgy	October - December 2023	Engineer & Analyst	Create a customized training program
6	Remote location of wind taps	Reduce motion wastage & defects	Changing the specimen drying method	Lab. CRM Metallurgy	August 2023	Analyst	Providing tissue in the lab. Metallography
7	The nearest wind tap is broken	Reduce motion waste	Fixing the wind tap	Lab. CRM Metallurgy	September 2023	Engineer	Make repair requests to civil engineering
8	Ineffective sandpaper storage	Reduce motion waste	Moving the emery bin	Lab. CRM Metallurgy	August 2023	Analyst	Move the emery bin next to the grinding machine
9	Sandpaper is taken in two sizes	Reduce motion waste	Change the method of taking sandpaper	Lab. CRM Metallurgy	Agustus 2023	Analysts & Laboratorians	Taking all sizes of sandpaper at once
10	5R principles are not given enough attention	Reduce over-processing	Review the 5S program	Lab. CRM Metallurgy	Oktober 2023	Engineer, Analis, Laboran	Create daily inspection forms for each machine in the lab. Metallography
11	There is no standardized number of samples in one mounting	Reduce defect waste	Create a standardized standard	Lab. CRM Metallurgy	Oktober – November 2023	Engineer, Analis	Discuss with analysts and laboratory assistants, create and socialize standard standards

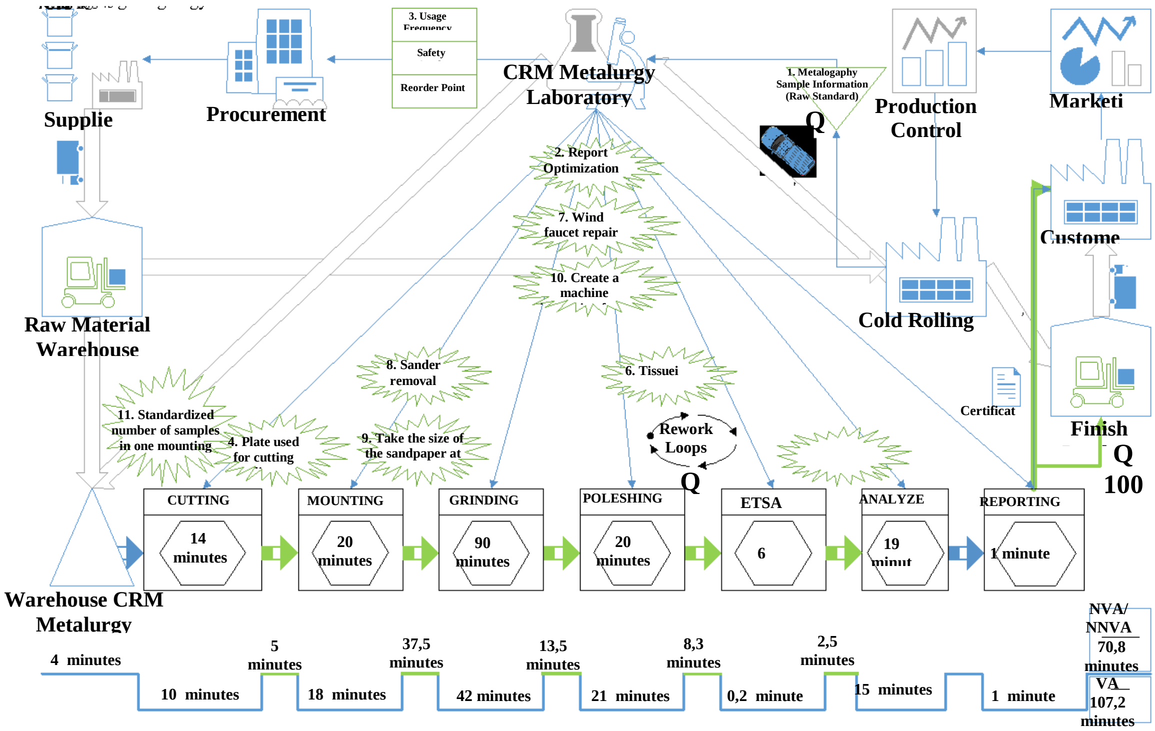

Fig 8. Future state value stream mapping

Discussion

Table 6 shows several activities that have decreased both in terms of the number of activities and the total time required. In operation activities, there was a decrease in the number of activities from 38 to 37 activities with a total time from 164 minutes to 148.5 minutes so a percentage of time reduction was obtained by 9%. Transportation activities have decreased the number of activities from 8 to 4 activities with a total time from 13 minutes to 6 minutes so a percentage of time reduction of 54% is obtained. For inspection and storage activities there is no decrease in terms of both the number of activities and the total time required. In the delay activity, there was no decrease in the number of activities, but there was a decrease in total time, from 16 minutes to 14.5 minutes so the percentage of time reduction was 9%.

Overall, the process in the CRM metallographic laboratory from the preparation process to the reporting of results has decreased from 58 activities to 53 activities with a total time from 202 to 178 minutes, resulting in a percentage decrease in time of 12%. After knowing the comparison of the initial PAM with the proposed PAM based on the number of activities and time, the next step is to compare the initial PAM and proposed PAM against the type of activity in the VA, NNVA, and NVA categories exposed in **Table 7**.

Based on **Table 8** the proposed improvements for the CRM metallographic laboratory are: 1). Make a standardized standard on how to detect CRC products with end-use pipes & tubes that are in Work In Process (WIP) status so that officers can know when the right time to start metallographic specimen preparation; 2). Create a report file with an Excel form in which there are certain formulas so that report preparation can be automated without retyping the identity of the sample to be reported; 3). Create a standardized standard on how to detect CRC products with end-use pipes & tubes that are in Work In Process (WIP) status, so that officers can know when the right time to start metallographic specimen preparation is; 4). Create a report file with an Excel form in which there are certain formulas so that report preparation can be automated without retyping the identity of the sample to be reported; 5). Calculate the frequency of use of each supporting material so that the value of safety stock, and reorder point are obtained to anticipate delays in material arrival so that waste waiting can be minimized; 6). Make an inventory of used plates and cutting pliers to make it easier to put together a collection of samples so that waiting and motion waste can be minimized; 7). Creating a training program devoted to discussing activities in the CRM metallographic laboratory starting from the preparation process to reporting results; 8). Provide tissue in the CRM metallographic laboratory area to facilitate officers in the specimen drying process so that motion and defect waste can be minimized; 9). Request repair of the wind tap to civil engineering so that officers do not need to walk far to the spare wind tap so that motion waste can be minimized; 10). Moving the emery storage area to make it easier for officers in the process of grinding samples so that motion waste can be minimized; 11). Taking the sandpaper size for the grinding process at once so that motion waste can be minimized; 12). Creating a daily inspection form for each machine in the CRM metallographic laboratory so that 5S activities can continue to be implemented and controlled; 13). Create a standard to determine the number of samples in one mounting so that defect waste can be minimized.

According to [28], the application of VSM in a "Lean Manufacturing Laboratory" with a projected focus on the service industry sector needs a VSM approach to ensure strong product and information flow within the company and also throughout the supply chain. Lean practices with lean strategies can be applied to laboratories for sustainable education systems [29]. The importance of lean laboratory layout design has been implemented by manufacturing and service companies [30]. Lean manufacturing has changed the way some companies produce products more efficiently by reducing cycle time, higher productivity, less variation in analysis methods that allow direct comparison of data over time, and improved quality [31]. Following [32], a lean assessment of the laboratory can identify three types of waste that are the main contributors to the problem with Pareto showing that 37.5% of the various wastes contribute to 51.4% of the problem. The direct and indirect impact of Industry 4.0 is to implement Industry 4.0 to reduce the level of waste in the quality control process [33]–[35].

IV. CONCLUSION

There are clear benefits for the Company in using Industry 4.0 in the lean implementation journey and supporting the manufacturing organization's efforts to become leaner by using Industry 4.0 capabilities and solutions.

a. Based on the identification of waste through the distribution of the seven waste questionnaire, it can be concluded that there are 7 wastes in the CRM Metallographic Laboratory, including over production in the form of too many samples and filling the metallographic sample storage area but has not disrupted the metallographic specimen preparation process, waste defects in the form of defects on the surface of the sample as a result of an inappropriate preparation process, storage waste (inventory) is in the accumulation of raw materials supporting the metallographic specimen preparation process but has not disrupted the preparation process and does not require additional costs, over processing occurs when a sample surface defect appears so that it requires a repetition process (rework) so that the defect can disappear, transportation waste occurs during the sample drying process which requires officers to bring samples to the wind tap located in the mechanical testing area, waste waiting occurs in the relatively long process of preparing the result reporting sheet, and the last waste is motion waste which occurs in the process of uniting a collection of small samples.

b. Based on the results of the questionnaire calculation, waste that often occurs in the lab. Metallography is waiting by 0.34, motion by 0.29, overprocessing by 0.12, defects by 0.1, transportation by 0.07, inventory by 0.05, and overproduction by 0.03.

c. Based on the improvement recommendations obtained from the proposed PAM and planned in the 5W + 1H table, there are 10 improvement recommendations which include, making SOP / TSE on how to detect CRC products with enduse pipes & tubes that are in Work In Process (WIP) status, automating the preparation process for reporting analysis results in excel, calculating the frequency of use of each supporting material, providing used plates and cutting pliers, create a training program devoted to discussing activities in the CRM metallographic laboratory from the preparation process to the reporting of results, provide tissue in the CRM metallographic laboratory area, make a request for repair of the wind tap to the civil engineering, move the emery storage, create a daily inspection form for each machine in the CRM metallographic laboratory, and create a Standard Operating Procedures (SOP) to determine the number of samples in one mounting so as to produce an overall time reduction of 12%, namely from 202 minutes, to 178 minutes. Value Added (VA) activities remain the same, namely 18 activities with a total time of 107.2 minutes, while Necessary Non-Value Added/Non-Value Added (NNVA/NVA) activities have decreased from 40 activities to 35 activities with a total time from 94.8 minutes to 70.8 minutes.

Recommendation

This is where we need to build an industry 4.0 ecosystem. As we know, several other countries synergize and collaborate in the implementation of Industry 4.0, both from government elements, industry players, academics and R&D, technical providers, consultants, as well as financial actors.

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