

Lean Manufacturing Implementation through Value Stream Mapping on Gold Products

Implementasi Lean Manufacturing melalui Value Stream Mapping pada Produk Emas

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Article Info	Abstract
<i>Article History :</i> Received: 27 May 2023 Accepted: 10 July 2023 Published: January 2024	The manufacturing process at UBPP Precious Metal Manufacturing Bureau involves many wasteful activities such as manual production records, lack of standardization and digitization, which can lead to lost time and non-conformities if something goes wrong. The purpose of the study is to identify and eliminate wastes in the manufacturing process using Value Stream Mapping (VSM) to achieve lean manufacturing. VSM approach to understand gold manufacturing mapped in the current state map and improvements applied to the future state map. The cycle time in the weight check, cleaning, press and engraving process for the gramasi variant is still above 7.2 seconds per pcs with a daily target of 9,000 pieces. Proposed improvements to eliminate waste such as equipment re-layout, rejuvenation of rolling equipment, punch, press, engraving can reduce cycle time below the targeted takt time. Keywords: Cycle Time, Lean Manufacturing, Manufacturing Gold, Value Stream Mapping.
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Info Artikel	Abstrak
<i>Riwayat Artikel :</i> Diterima: 27 Mei 2023 Disetujui: 10 Juli 2023 Dipublikasikan: Januari 2024	<i>Proses manufaktur di Biro Manufaktur Logam Mulia UBPP melibatkan banyak kegiatan yang boros seperti catatan produksi manual, kurangnya standarisasi dan digitalisasi, yang dapat menyebabkan hilangnya waktu dan ketidaksesuaian jika terjadi kesalahan. Tujuan penelitian ini yaitu untuk mengidentifikasi dan mengeliminasi wastes dalam proses manufacturing menggunakan Value Stream Mapping (VSM) untuk mencapai lean manufacturing. Pendekatan VSM untuk memahami manufacturing emas yang dipetakan dalam current state map serta improvement yang diterapkan pada future state map. Cycle time di proses weight check, cleaning, press dan gravir untuk varian gramasi masih di atas 7,2 detik per pcs dengan target harian 9,000 keping. Usulan improvement menghilangkan waste seperti re-layout equipment, peremajaan peralatan rolling, punch, press, gravir dapat menurunkan cycle time dibawah takt time yang ditargetkan.</i> Kata Kunci: Cycle Time, Lean Manufacturing, Manufacturing Emas, Value Stream Mapping.
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INTRODUCTION

Gold has a long and unique history as a financial asset over the past 6,000 years (He *et al.*, 2018). Recently, there has been a growing body of research assessing whether gold acts as a haven for investors in times of severe market stress. Since the 2008 financial crisis, gold has gained new prominence for investors and researchers as its price rose from \$252 in July 1999 to 1,900 dollars per ounce briefly on September 5, 2011, and many Exchanges Traded Funds (ETFs) were established to make it easier for smaller investors to buy gold (He *et al.*, 2018). Gold consumption based on Metal Focus data is used in various sectors such as jewelry, technological materials, investment, and Central Bank needs (Fritz *et al.*, 2020). From this data, the largest consumption of gold, namely jewelry, bar products, and coins, then the investment sector, in 2021–2022 the need in the investment sector has increased after recovering from the impact of Covid-19.

In Indonesia, based on data from the Directorate General of Mineral and Coal, there are 15 Gold Producers. One of the largest producers is PT. Antam, Tbk. (ANTAM). ANTAM is a diversified and vertically integrated mining company with assets spread across several regions in Indonesia. Exploration, mining, processing, and refining, as well as the marketing of various commodities, are among its activities. The main commodities marketed are the Precious Metals group such as gold and silver. Dore bullion production from mining company Contract of Work to be refined at ANTAM's Precious Metal Processing and Refining Business Unit (UBPP LM). If the analysis is carried out every month, based on the UBPP LM Gold Production Target Vs Realization data graph where the target and realization Linear charts intersect in May 2021 so that the Target Linear Chart starts above the Linear Realization chart. Figure 1 also shows the realization of < target, namely a gap of -6% to -69%. This will be a problem in the future if UBPP LM does not make improvements or innovations related to the gap that occurs in productivity control at UBPP LM, especially the Manufacturing Bureau.

The process step starts from the weighing process to the engraving process. In the production process of gold precious metals, there are still non-value-added activities such as recording/recording production manually, there is no standardization and digitalization which causes loss of time, operators play an important role in the production process so that if something goes wrong it can cause a mismatch in the product produced. The application of lean and the identification of wastes or non-value-added activities is one of the things that needs to be considered because it has an impact on productivity that occurs in the Manufacturing Bureau.

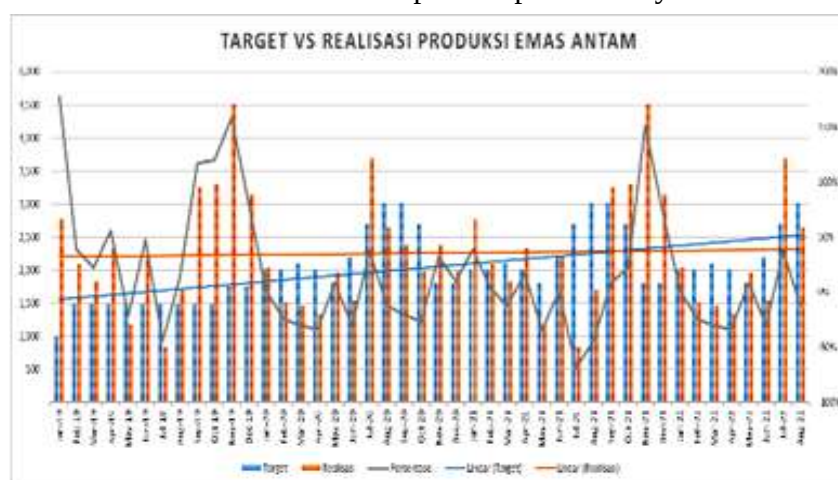


Figure 1. Target vs Production Realization

Source: ANTAM's Production Data, 2019-2022.

In the production process of precious metal gold, there are still non-value-added activities such as manual recording/production tracking, lack of standardization, and digitalization, resulting in loss of time. Operators play a crucial role in the production process, and any mistakes can lead to product discrepancies. Lean is defined as a process that focuses on the elimination of waste, where every process in producing goods or services should provide value (Jacobs *et al.*, 2014). The lean theory is based on principles of reducing waste, lowering inventory and operational costs, improving product quality and productivity, and ensuring worker comfort (Womack *et al.*, 2007). Activities that do not add value should be eliminated from the process stages as they do not directly contribute to the desired outcomes for the customer. Waste is defined as something that does not add value from the customer's perspective (Womack & Jones, 2003). The value stream mapping (VSM) technique was used for the identification and elimination of waste in the UBPP LM Manufacturing Bureau to achieve leanness. This research will be done by mapping the current state map to identify the waste and then developing solutions to reduce or eliminate it, which will be mapped back to the future state map.

The research purpose is to analyze the implementation of lean manufacturing through VSM on gold products. The benefits of the research are to provide references to UBPP LM as a reference in eliminating or minimizing waste or wastes. In addition, it is expected to increase the effectiveness and efficiency of operational activities at UBPP LM which will go hand in hand with increased productivity, so that it has an impact on revenue or profit for the company and provide additional references or knowledge about the application of Lean Manufacturing with the VSM method in gold precious metal processing and refining operations and become a reference or comparison for other similar studies.

LITERATURE REVIEW

The concept of lean manufacturing was first introduced by Taiichi Ohno, known for developing the Toyota Production System (TPS). Ohno pioneered the lean manufacturing strategy in the 1950s (Ohno, 1988). The five main principles of lean manufacturing consist of specify value, identify the whole value stream, flow, pull system and perfection (Womack & Jones, 2003; Rother & Shook, 2003). Waste refers to any activity that consumes time, resources, or space without adding value to the product or service (Madsen & Madsen, 2016). By eliminating this waste, it is expected that operational costs will be reduced, productivity will increase, and product quality and on-time delivery will be improved (Hariram *et al.*, 2020). Ohno (1988) identified seven types of waste which are overproduction, unnecessary inventory, inefficient transportation, unnecessary motion, waiting, defects and overprocessing.

According to Mark & Sheila (2008), the current state map and future state map consist of three main components into: (1) production process flow; (2) information/communication flow; and, (3) timeline/distance traveled. Four main stages in creating value stream mapping consists of: (1) determining the product and product family; (2) creating the current state map; (3) creating the future state map; and, (4) designing the improvement plan (Abdulmalek & Rajgopal, 2007).

Lean manufacturing is a production management approach that aims to eliminate waste and improve efficiency throughout the value stream (Seth & Gupta, 2005). Introduced by Taiichi Ohno (1988), it emphasizes principles such as specifying value, identifying the value stream, ensuring flow, utilizing a pull system, and striving for perfection. By eliminating various forms of waste, including over-production, unnecessary inventory, inefficient transportation, waiting, defects, and

overprocessing, organizations can reduce costs, enhance productivity, and improve product quality and delivery. Value stream mapping (VSM) is a key tool in lean manufacturing for analyzing and optimizing the flow of materials and information. Overall, embracing lean principles empowers organizations to achieve higher levels of operational effectiveness and customer satisfaction.

METHOD

According to Blumberg *et al.* (2014), research design is a plan to achieve research objectives and answer research questions. In other words, research design is a set of procedures and methods used to analyze and collect data in order to determine the variables that will be the subject of the research. In this study, the researcher adopts a quantitative approach which aims to present facts, processes, and variables related to the object of study, including the relationships between variables. Data collects from the manufacturing unit, specifically numerical data or operations related to the processing and refining of precious metals.

This research adopts the same research framework as Seth & Gupta (2005) and Vinodh *et al.* (2010), which is derived from the model developed by Rother & Shook (2003). Rother & Shook (2003) developed a model to achieve lean manufacturing conditions based on the elimination of various types of waste through VSM. The process analysis is conducted by gathering information through various questions with experts at the shop floor level, workers, and by directly participating in measuring the time for various processes. According to Patel *et al.* (2015), the various steps in the VSM methodology consist of: (1) To gather data, the following information needs to be collected are customer requirements (product family, quantity and timing of required products, product varieties, quantity of products shipped), information flow (customer forecast information, departments involved in the process, lead time before processing, information about supplier orders) and physical flow (desired products and their timing, quantity of different products desired, products shipped, delivery lead time, etc.); (2) Once the data is gathered, the next step is to create the current state map which consist of understanding customer requirements, creating a process flow map, creating an information flow map, creating a material flow map and creating a timeline; (3) After creating the current state map, the seven types of waste should be identified among all the processes, and a prioritized chart should be drawn to identify lean tools in Table 1 to be applied for process improvement to reduce the total lead time; and, (4) Creating a future state map, involves improving the existing flow by utilizing VSM, which ultimately helps reduce inventory, waiting time, lead time, and increase productivity. In this research, the cost of the required improvements and the savings after implementing improvements in the production process will be calculated. The focus of this study is on the products produced by the process.

Manufacturing with the following technical condition during data sampling, i.e.: (1) all small bars ranging from 0.5 grams to 100 grams have the same production process; (2) the parameters of the metallurgical process in gold processing are assumed to remain constant; (3) the sequence of production processes in processing remains unchanged throughout the research, starting from weighing - melting - large rolling - cutting - finishing rolling - punching - weighing check - cleaning - annealing - pressing – engraving; (4) Operators at each process point are assumed to have the same working capabilities; (5) Machines and equipment are in good condition and functioning normally during data collection; and, (6) Time measurements for each process are based on the time taken for each respective process during data collection.

Table 1. VSM Tools

Tools	Parameter
Process activity mapping	Identifying lead time and productivity opportunities:
Demand amplification mapping	Volume over time
Quality filter mapping	Failures in products, scrap, and services
Production variety funnel	Number of product variants in the manufacturing process flow
Value adding time profile	Value added, non-value added, necessary non-value added

Source: Patel (adapted), 2015.

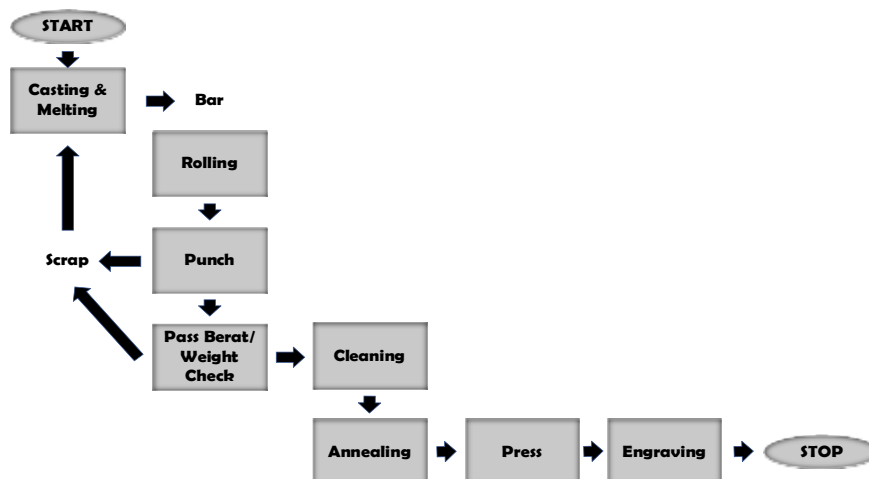


Figure 2. General Flowchart of Gold Precious Metal Products

Source: ANTAM Internal Data (reprocessed), 2023.

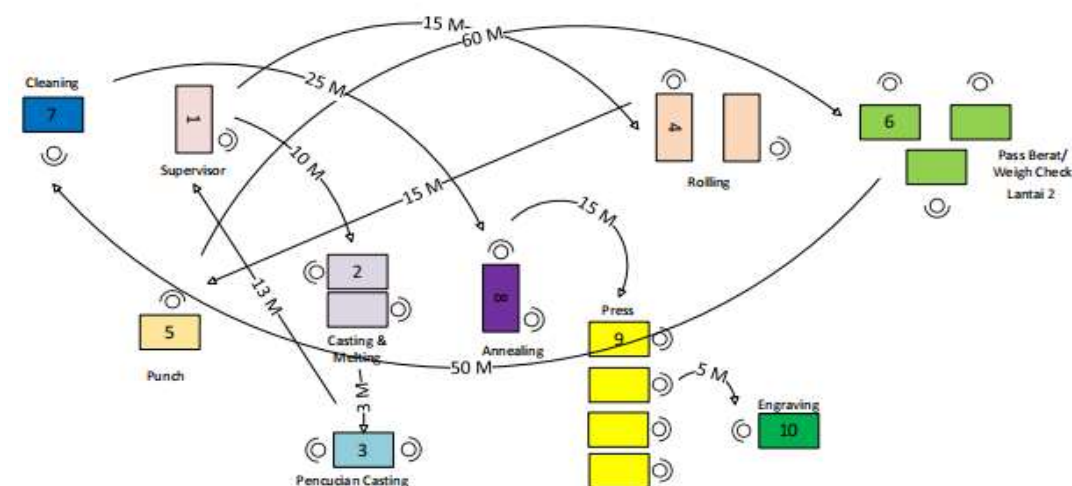


Figure 3. Current Layout Manufacturing Process

Source: ANTAM Internal Data (reprocessed), 2023.

RESULTS

After the dore refining process, the precious metal manufacturing production process is carried out. The following some of the process steps as shown in Figure 2. In next step, we are creating current state map. It is necessary to have current layout in the manufacturing area to reduce or eliminate of waste to simplified of flow process. Figure 3 shows the current flow of raw material until good finished.

In calculating the cycle time of the manufacturing process, broadly speaking, it can be divided into the following steps as casting and melting, rolling, punching, weight check, cleansing, annealing, pressing and engraving. To obtain the cycle time, the researcher assumes the duration required to produce each gram variant (1 gram, 2 grams, 3 grams, 5 grams, 10 grams, 25 grams, 50 grams, and 100 grams) using a 15 kg source of granules or scraps for each gram variant. Based on the observation summarize in Table 2, the average daily demand is 9,000 pcs per day, with a working time of 18 hours/1,080 minutes/64,800 seconds per day. Therefore, the calculation of the Takt Time (available time per day/daily demand) is 64,800 seconds / 9,000 pcs = 7.2 seconds/pcs. Figure 4 showed that there are five manufacturing processes that significantly affect their respective gram variations under a takt time of 7.2 seconds. These five processes are casting & melting, large roll, finishing roll, punch, and annealing. Among these five processes, the cycle time falls below the takt time, indicating that they can meet the production targets.

Table 2. Summary Cycle Time of Variant Grammage

Activities	1 gr	2 gr	3 gr	5 gr	10 gr	25 gr	50 gr	100 gr
Casting and Melting (Second)	1937	1939	1997	1995	1995	2000	2016	1995
Big Rolling (Second)	448	448	812	935	165	391	330	270
Finishing Rolling (Second)	450	500	947	647	520	722	245	185
Punch (Second)	11228	3750	6000	3630	1500	1837	1650	960
Weight Check (Second)	24000	65250	56750	61500	29580	9060	4170	1998
Cleaning (Second)	6000	14250	9480	5270	8250	4384	3120	2085
Annealing (Second)	18000	4821	8340	9000	1902	1200	300	150
Press (Second)	204000	69000	63000	69075	25450	15765	6915	3305
Engraving (Second)	-	-	-	-	22500	1635	1788	3150
Total (Second)	266063	159958	147326	152052	91862	36994	20534	14098
Pcs (15 kgs to Variant grammage)	15000	7500	5000	3000	1500	600	300	150
Cycle Time per Pcs	17.74	21.33	29.47	50.68	61.24	61.66	68.45	93.99

Source: ANTAM Internal Data (reprocessed), 2023.

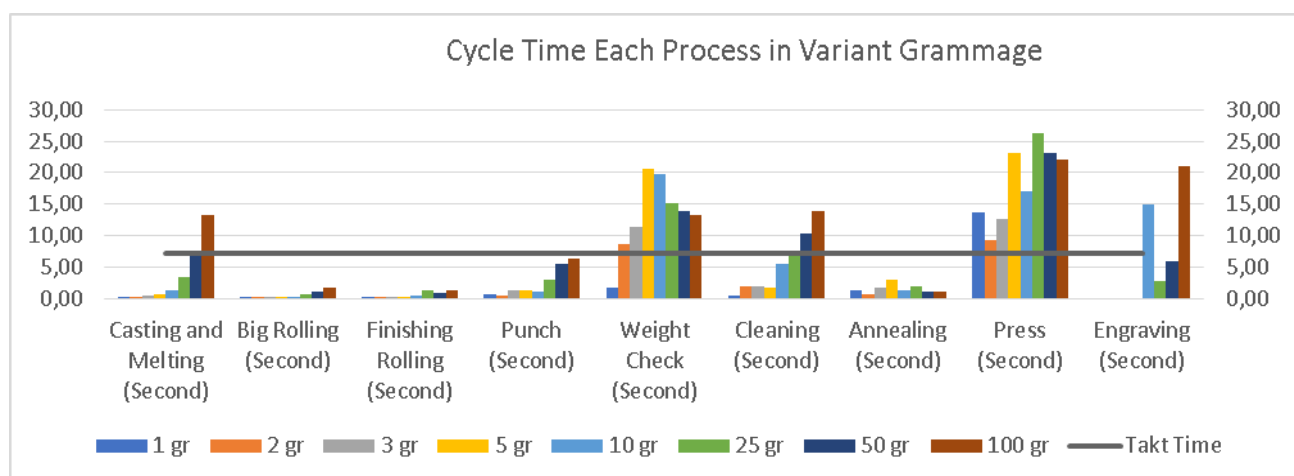


Figure 4. Current Layout Manufacturing Process

Source: ANTAM Internal Data (reprocessed), 2023.

Table 3. Process Activity Mapping in Manufacturing Process

No	Step	Flow	Machine	Distance	Times (S)	People	Operation	Transport	Inspect	Store	Delay	Ket.	% NVA Activities		
Melting dan Casting															
1	Weighing the metal scraps and granules for melting	I	Induction Furnace Machine	13 Meters	60	2 Person						VA	6%		
2	Start Up Mesin Induction Furnace	O			120						NNVA				
3	Put crucible inside Induction Furnace Machine	O			60						NNVA				
4	Feed raw material into crucible inside Induction Furnace Machine	O			150						NNVA				
5	Preparing the mold by applying a coating of graphite and heating it with a flame blender	O			200						NNVA				
6	Melting scrap dan granule	O			760						VA				
7	Lifting and pouring the material from the crucible into the mold	T			90						NNVA				
8	Removing the blank from the mold and taking the material to be placed into HCL (Hydrochloric Acid	T			75						NNVA				
9	Rinsing the blank by using water	O			300						NNVA				
10	Shutoff Induction Furnace Machine	O			120						NVA				
11	Weighing the material that has been molded	I			60						VA				
Rolling															
1	Weighing the pure metal material to be rolled	O	Big Roll Kachelman Getriebe Machine and Semi Roll Finishing	28 Meters	25	2 Person						NNVA	13%		
2	Cleaning the dirty parts of the blank	O			60										NVA
3	Adjusting the height position of the rolls to accommodate the required thickness of the blank to be rolled	O			30										NNVA
4	Rolling the gold ingot with a maximum reduction of 1 mm	O			200										VA
5	Rolling the sheet metal pieces with a semi-roll finishing machine until the desired thickness is achieved	O			115										VA
6	Weighing the rolled metal material	I			25										NNVA
Punch															
1	Installing the punch blade and tightening the bolts.	O	Punch SEYI SN1-60/25	15 Meters	120	1 Person						NNVA	10%		
2	Stabilizing the upper and lower blades by adjusting the bottom bearings.	O			100										NNVA
3	Pressing the pedal to open the wheel on the punch blade.	O			30										NNVA
4	Stabilizing the position of the punch blade to the ideal positio	I			120										NNVA
5	Checking the punch blade setting using the automatic mode.	I			90										NNVA
6	Performing the punching process using the pedal and then weighing the output to determine the desired weight range	O			400										VA
7	If the weight exceeds the desired range, the material undergoes another rolling process before being punched again	D			100										NVA
Weight Check															
1	Weighing the pure metal material for the weight check.	O	Filing, Container and Weighing Scale	60 Meter	30	3 Person						NNVA	91%		
2	Calibrating the weighing scale without any blank/material on it.	I			90										NNVA
3	Filing the edges of the blank	O			920										NVA
4	Taking each blank and weighing them one by one	I			68										NNVA
5	If the blank is heavier than the desired weight, file the edges of the blank to meet the criteria of not being less than 0.000 and not exceeding 0.003 in weight.	D			890										NVA
Cleansing															
1	Weighing the pure metal material to be cleansed	I	Container and Alcohol	50 Meter	60	1 Person						VA	77%		
2	Placing the blank in a container filled with alcohol to ensure it is fully submerged	O			425						NNVA				
3	Drying the blank using a cloth or towel and placing it on a dry tray	S			1600						NVA				
Annealing															
1	Turning on the annealing machine with an ammonia temperature of 900°C and furnace temperature of 800°C using the igniter.	O	Anneling Furnace Belt Machine	25 Meter	30	2 Person						NNVA	20%		
2	Adjusting the belt speed and ammonia gas flow according to the variant of the blank to be annealed	O			10										NNVA
3	Placing the blank on the belt of the furnace	O			30										NNVA
4	Performing the annealing process on the blank	O			50										VA
5	Retrieving the blank and allowing it to cool down to room temperature	S			30										NVA
Press															
1	Turning on the press machine	O	Press MDM Combipress 300T, 200T, 40T Machine	15 Meter	30	4 Person						NVA	73%		
2	Taking the blank and placing it on the die and positioning it on the bolster plate	T			240										NVA
3	Performing manual adjustments on the bolster, meter setting, and die clearance	I			600										NVA

4	Performing pressing according to the required tonnage for the blank	O	850			VA
5	Repeating the pressing process to achieve the desired relief result	O	1550			NVA
6	Inspecting the quality and separating the good quality blanks from the rejected ones	I	35			NVA
Engraving						
1	Setting the zero point on the engraving mold	O	150			NVA
2	Running the engraving program on the PC	O	30			NNVA
3	Inputting the serial number to be engraved on the engraving PC	O	540			NVA
4	Arranging the blanks on the engraving machine	O	300			NVA
5	Activating the print mode on the engraving PC to initiate the engraving tool on the gold bar surface	O	480	1 Person		VA
6	Recording the engraved serial numbers in the serial number book	O	460			NVA
7	Updating the serial number on the engraving PC	O	470			NVA
8	Retrieving the arranged blanks with the engraved serial numbers	S	600			NVA
9	Re-weighing the blanks for final stock verification	I	120			NVA

Source: ANTAM Internal Data (reprocessed), 2023.

Table 4. Proposed Improvements to the Current Value Stream

No	Objective	Process Category	Improvement
1	Elimination of unnecessary material transportation	Layout	Performing a re-layout for the positioning of equipment in the manufacturing area
2	Elimination of unnecessary waiting time	Casting and melting	The use of an automatic shut-off system for the induction furnace
3	Elimination of defects and unnecessary overproduction	Rolling	The use of a High-Pressure Steam Cleaner system to clean gold blanks from dirt or stains
4	Elimination of defects and unnecessary overproduction	Punch	Implementing a quality checking sheet based on the defined quality standards and control in the punch process
5	Elimination of inappropriate processes and overproduction	Weight check	Performing modernization and upgrading of the punch machine
6	Elimination of waiting processes	Cleaning	Implementing operator rotation within a work group and implemented Ultrasonic Cleaning System
7	Elimination of inappropriate processes, waiting time, and overproduction	Press	Performing modernization by upgrading the press machine with a high-speed and high-precision machine
8	Elimination of inappropriate processes and waiting time	Engraving	Adding an engraving machine with a faster speed compared to the existing one. For automatically generated serial numbers, synchronization is required between the internal ANTAM system and the engraving PC

Source: Primary data (processed), 2023.

Table 5. Before and After Improvement for Cycle Time

Parameter	100 gr	50 gr	25 gr	10 gr	5 gr	3 gr	2 gr	1 gr
Total cycle time before improvement (second)	14148	20584	37044	91912	152102	147376	160008	266120
Total cycle time after improvement (second)	6501	8571	13520	27109	42960	44228	42407	92537
Decrease in Percentage	54.05	58.36	63.5	70.51	71.76	69.99	73.5	65.23

Source: Proposed by Authors, 2023.

In order to identify waste, it is highly recommended that companies carry out process activity mapping. Table 3 summarizes the process activity mapping in manufacturing process for the products in this research. Next step is creating future state map in which the following are some improved proposals shown in Table 4 to eliminate waste based on the waste that has been identified the manufacturing process.

To identify the proposed improvements to the value stream, a future state map will be compiled to eliminate the waste that occurs. Table 5 summarizes the comparison of cycle time, total non-value added and total lead time before and after improvement. Based on the table, it is found that with a mass of 100 grams the total cycle time before improvement is 14148 seconds and after improvement is 6501 seconds so that it has decreased by 54.05 percent. At a mass of 50 grams the total cycle time before improvement is 20584 seconds and after improvement is 8571 seconds so that it has decreased by 58.36 percent. At a mass of 25 grams the total cycle time before improvement is 37044 seconds and after improvement is 13520 seconds so that it has decreased by 63.5 percent. At a mass of 10 grams the total cycle time before improvement is 1912 seconds and after improvement is 27109 seconds so that it has decreased by 70.51 percent. At a mass of 5 grams the total cycle time before improvement is 152102 second and after improvement is 42960 second so that it has decreased by 71.76 percent. At a mass of 3 grams the total cycle time before improvement is 147376 seconds and after improvement is 44228 seconds so that it has decreased by 69.99 percent. At a mass of 2 grams the total cycle time before improvement is 160008 seconds and after improvement is 42407 seconds so that it has decreased by 73.5 percent. And, at a mass of 1 gram the total cycle time before improvement was 266120 second and after improvement was 92537 second, resulting in a decrease of 65.23 percent. This decline occurred because the non-value-added value was reduced or eliminated with the improvement. From the comparison of cycle time before and after improvement in Table 5, grammatical variance shows a significant decrease.

It is found that based on Table 6, with a mass of 100 grams total non-value added before improvement is 7920 seconds and after improvement is 580 seconds so that it has decreased by 92.68 percent. At a mass of 50 grams the total non-value added before improvement is 11372 seconds and after improvement is 858 seconds so that it has decreased by 92.46 percent. At a mass of 25 grams the total non-value added before improvement is 21780 seconds and after improvement is 1436 seconds so that it has decreased by 93.41 percent. At a mass of 10 grams the total non-value added before improvement is 60379 seconds and after improvement is 2345 seconds so that it has decreased by 96.12 percent. At a mass of 5 grams the total non-value added before improvement is 99883 second and after improvement is 3706 second so that it has decreased by 96.29 percent. At a mass of 3 grams the total non-value added before improvement is 95642 seconds and the total non-value added after improvement is 4351 seconds so that it has decreased by 95.45 percent. At a mass of 2 grams the total non-value added before improvement is 109221 seconds and after improvement is 4507 seconds so that it has decreased by 95.87 percent. And, at a mass of 1 gram the total non-value added before improvement was 142455 second and after improvement was 6779 second, resulting in a decrease of 95.24 percent. Based on Table 6, it is found the decrease is very significant; non-value added show waste that must be eliminated with proposed improvements.

Based on Table 7, it is found with a mass of 100 grams total lead time before improvement is 239 minutes and after improvement is 109 minutes so it has decreased by 54.33 percent. At a mass of 50 grams the total lead time before improvement is 346 minutes and after improvement is 154 minutes so that it has decreased by 55.49 percent. At a mass of 25 grams the total lead time before

improvement is 620 minutes and after improvement is 250 minutes so that it has decreased by 59.68 percent. At a mass of 10 grams the total lead time before improvement is 1535 minutes and after improvement is 492 minutes so that it has decreased by 67.95 percent. At a mass of 5 grams the total lead time before improvement is 2538 minutes and after improvement is 824 minutes so that it has decreased by 67.53 percent. At a mass of 3 grams the total lead time before improvement is 2459 minutes and after improvement is 821 minutes so that it has decreased by 66.61 percent. At a mass of 2 grams the total lead time before improvement is 2670 minutes and after improvement is 815 minutes so that it has decreased by 69.48 percent. And, at a mass of 1 gram, the total lead time before improvement was 4437 minutes and after improvement was 1822 minutes, resulting in a decrease of 58.94 percent. Total lead time significant decrease after improvement.

In Table 8 summary cycle time for variant grammage which have been improved with. The cycle time changes significantly for each gram variation, particularly in the weight check, cleaning, pressing, and engraving processes. In the cycle time shown in Figure 5 based on the activity data provided, it can be seen that the time required for each activity differs depending on the product weight variation. It can be concluded that the time required for each activity is different depending on the product weight variation. In the casting and melting activity, the time required is relatively stable for each product weight variation. Big rolling and finishing rolling show significant time variations depending on the product weight. In general, the heavier the product, the longer it takes to complete the activity. However, in the punch activity, there is a notable variation in the time taken. The time required for the 1 gram weight variant is 11,228 seconds, while for the 100 gram weight variant it is only 960 seconds. The total time required for all activities also varies according to the variation in product weight. There is an increase in time with an increase in product weight. In addition, the amount of production that can be achieved in a given period of time also varies depending on the weight of the product. In general, the heavier the product, the lesser the amount of production tends to be. So, before the improvement, the cycle time for these four processes was still above the takt time. After eliminating several non-value-added activities and implementing proposed improvements, the cycle time is now below the takt time.

Table 6. Before and After Improvement for Non-Value Added

Parameter	100 gr	50 gr	25 gr	10 gr	5 gr	3 gr	2 gr	1 gr
Total non-value added before improvement (second)	7920	11372	21780	60379	99883	95642	109221	142455
Total non-value added after improvement (second)	580	858	1436	2345	3706	4351	4507	6779
Decrease in Percentage	92.68	92.46	93.41	96.12	96.29	95.45	95.87	95.24

Source: Proposed by Authors, 2023.

Table 7. Before and After Improvement for Total Lead Time

Parameter	100 gr	50 gr	25 gr	10 gr	5 gr	3 gr	2 gr	1 gr
Total lead time before improvement (second)	7920	11372	21780	60379	99883	95642	109221	142455
Total lead time after improvement (second)	580	858	1436	2345	3706	4351	4507	6779
Decrease in Percentage	92.68	92.46	93.41	96.12	96.29	95.45	95.87	95.24

Source: Proposed by Authors, 2023.

Table 8. Cycle Time After Improvement

Activities	1 gr	2 gr	3 gr	5 gr	10 gr	25 gr	50 gr	100 gr
Casting and Melting (Second)	1879	1881	1937	1935	1935	1940	1955	1935
Big Rolling (Second)	402	402	729	840	148	351	296	242
Finishing Rolling (Second)	404	449	851	581	467	648	220	166
Punch (Second)	10058	3359	5375	3252	1344	1646	1478	860
Weight Check (Second)	2258	6140	5340	5787	2783	852	392	188
Cleaning (Second)	2547	6049	4024	2237	3502	1861	1324	885
Annealing (Second)	18000	4821	8340	9000	1902	1200	300	150
Press (Second)	56932	19256	17582	19277	7103	4400	1930	922
Engraving (Second)	-	-	-	-	7875	572	626	1103
Total (Detik)	92480	42357	44177	42909	27058	13470	8522	6451
Pcs (15 kgs to Variant grammage)	15000	7500	5000	3000	1500	600	300	150
Cycle Time per Pcs	6.17	5.65	8.84	14.30	18.04	22.45	28.41	43.01

Source: Proposed by Authors, 2023.

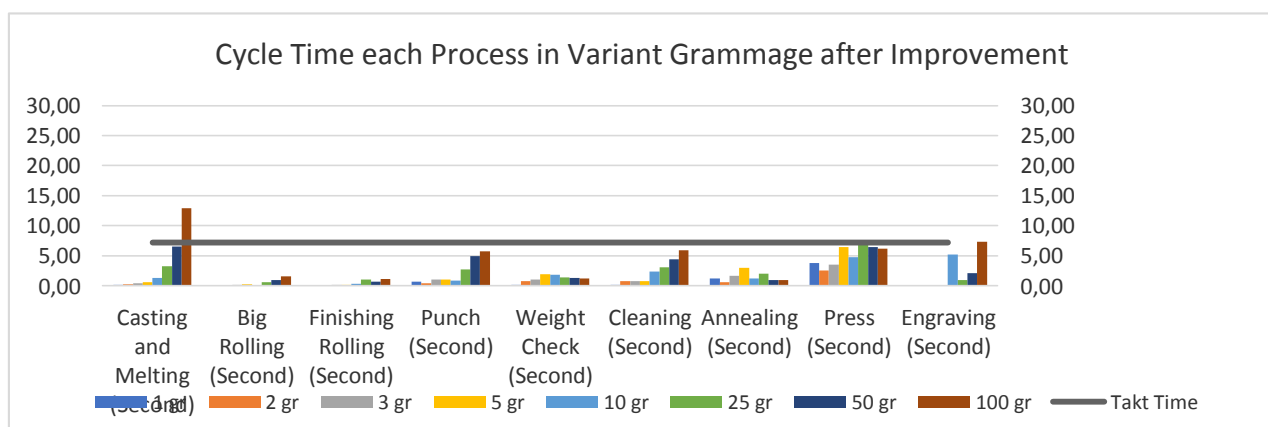


Figure 5. Cycle Time with Takt Time after Improvement

Source: Proposed by Authors, 2023.

In Table 8 summary cycle time for variant grammage which have been improved with. The cycle time changes significantly for each gram variation, particularly in the weight check, cleaning, pressing, and engraving processes. In the cycle time shown in Figure 5 based on the activity data provided, it can be seen that the time required for each activity differs depending on the product weight variation. It can be concluded that the time required for each activity is different depending on the product weight variation. In the casting and melting activity, the time required is relatively stable for each product weight variation. Big rolling and finishing rolling show significant time variations depending on the product weight. In general, the heavier the product, the longer it takes to complete the activity. However, in the punch activity, there is a notable variation in the time taken. The time required for the 1 gram weight variant is 11,228 seconds, while for the 100 gram weight variant it is only 960 seconds. The total time required for all activities also varies according to the variation in product weight. There is an increase in time with an increase in product weight. In addition, the amount of production that can be achieved in a given period of time also varies depending on the weight of the product. In general, the heavier the product, the lesser the amount of

production tends to be. So, before the improvement, the cycle time for these four processes was still above the takt time. After eliminating several non-value-added activities and implementing proposed improvements, the cycle time is now below the takt time.

Discussion

Layout is one of the key decisions that determines long-term operational efficiency (Heizer *et al.*, 2017). Layout has strategic implications as it sets the competitive priorities of an organization in terms of capacity, processes, flexibility, costs, as well as the quality of work life, customer contact, and image. With the current conditions before and after improvement the distance that the product needs to travel from the beginning to the end of the process is 208 meters to 84 meters for variants weighing 1 to 5 grams, and 213 meters to 89 meters for variants weighing 10 to 100 grams.

The implementation of Real-Time Machine Status Advanced Analytics, which can be applied in this production process. This system is IT-based and integrates installed sensors, connected to various equipment using a Dynamic Control System (DCS). DCS is a system used to control complex industrial processes automatically, including production processes in the manufacturing industry. DCS can control the sensors installed in the equipment. Generally, DCS works with a Programmable Logic Controller (PLC) as the main processor. The NVA reduce from 6 percent to 3 percent due to minimization of operator waiting time. The rolling process does not result in any dirt or contaminants. However, using sandpaper for sanding is not an effective method as it is not the primary task. Therefore, the researcher proposes the installation of a Steam Cleaner. This equipment utilizes high-pressure steam to clean the surface of the gold blank from dirt or stain. The effect of cleaner machine in rolling process can reduce NVA from 13 percent to 3 percent.

This standardization includes the addition of quality standards for products through the creation of quality standard processes and quality standard records. The function of the quality standard process is to serve as a reference for production. The Quality department (QC) establishes the Quality Product Standard, which serves as the basis for creating the Quality Process Standard. The aim of implementing this quality process standard is to ensure that the product development process is structured and controlled. The NVA in punch process arise from over production waste with not match with mold requirement, 10 percent of cycle time in punch process can eliminate if the quality check sheet implemented.

The activity is considered highly conventional and does not reflect modern manufacturing processes. It contributes waste to the manufacturing process as it involves repetitive steps and generates scrap in the form of gold dust, which needs to be re-melted. Moreover, there is a potential risk of losing the gold dust scrap due to exposure to the air or improper handling during the filing or container placement process. With the modernization and upgrading of the punch machine, the process of filing the blank and achieving precise blank weights according to the requirements can be achieved. As a result, the NVA activity of filing or container placement process will be eliminated by 91 percent to 0 percent.

To eliminate waste in this process, installing an Ultrasonic Cleaning System is recommended. This equipment utilizes ultrasonic waves to clean material surfaces effectively. The system consists of a cleaning tank, an ultrasonic generator, and transducers. The generator produces high-frequency signals that are transmitted to the transducers, which then convert the signals into ultrasonic vibrations. These vibrations create pressure waves inside the tank, assisting in the removal of dirt

and particles from the material surface. The NVA in cleaning process will be eliminated from 77 percent to 19 percent.

The manual setting of the bolster, meter setting, and die holder performed by the operator, as well as the repeated pressing required for variants weighing 5 grams and above due to the different reliefs on both sides of the blank, it is necessary to modernize the press equipment. With this modernization, the activities of setting the bolster, meter setting, die holder and repeated pressing for blanks weighing 5 grams and above can be eliminated. The NVA time for these pressing activities will decrease from 73 percent to 1 percent. The serial number engraving on gold blanks and to increase the engraving speed, an improvement that can be implemented is the addition of a faster engraving machine compared to the existing one. Furthermore, to generate and assign serial numbers, an integrated system between existing in UBPP and the engraving PC is required. This system would allow the serial numbers to be directly stored and plotted on the engraving template within the PC. With the addition of the engraving machine, the manual labor involved in the engraving process can be eliminated. As a result, the NVA time for this activity will decrease from 65 percent to 0 percent.

Waste in the precious metal manufacturing process was identified using value stream mapping methodology, including inappropriate processes, over-processing, product defects, and waiting. The current state map for all gram sizes, with a total lead time of 9,557 seconds, total NVA time of 524,090 seconds, and cycle time before improvement of 611,461 seconds. Based on the designed future state map, improvements were achieved in the overall value stream. The cycle time decreased by 68.76 percent, total lead time decreased by 64.38 percent, and total non-value-added time decreased by 95.52 percent. To eliminate waste in the precious metal manufacturing process, several improvements can be implemented by UBPP LM, such as equipment re-layout, standardization/checking sheet improvement in the manufacturing section, installation of real-time machine status integrated with the DCS system, and upgrading and modernization of equipment in the casting and melting, rolling, punch, cleaning, and engraving processes. The estimated cost for the proposed improvements is Rp. 42,956,401,917.

In the research conducted by Fernando & Noya (2014) that to minimize waste in the production process is to reduce the amount of NVA activity time or eliminate it. Meanwhile, Setiawan & Rahman (2021) explains that in order for the production system to run in accordance with the procedure, improvements need to be made to minimize the identified waste, namely providing an understanding of product knowledge to employees, increasing the number of material handling (forklifts), and making work shelves in the production area to make it easier for operators to find work tools. This research, however, aims to analysis of lean manufacturing implementation through value stream mapping on gold products. The results show that proposed improvements to eliminate waste such as equipment re-layout, rejuvenation of rolling equipment, punch, press, and engraving, can reduce cycle time below the targeted takt time.

CONCLUSION

This research is conducted utilize secondary data made available by UBPP LM. Despite the fact that the data present a tremendous opportunity, they also present some constraints. In particular, the data taken by sampling for each variant grammage makes it possible to query the sample's representativeness. Additionally, there are issues with self-reported performance data and potential

single respondent bias. Despite these limitations, the data provide a comprehensive depiction of the manufacturing practices of numerous organizations.

Future research on lean manufacturing should explicitly account for the effects of size and industry, based on the findings. Positive findings regarding the effect of context on the implementation of lean practices suggest that additional environmental factors should be investigated in future studies. In particular, prospective research on lean manufacturing in context may consider the effects of environmental dynamism, complexity and cost reduction.

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