INTERNATIONAL JOURNAL OF SUSTAINABLE CONSTRUCTION ENGINEERING AND TECHNOLOGY
VOL. 14 NO. 5 (2023) 290-304

IJSCET

http://publisher.uthm.edu.my/ojs/index.php/ijscet

ISSN : 2180-3242 e-ISSN : 2600-7959

International Journal of Sustainable Construction Engineering and Technology

Identifying and Eliminating Waste in a Coal Mining Industry: The Value Stream Mapping Analysis

Menik Yuni Indriati[1*], Raja Zuraidah Rasi[1], Bambang Setiaji[2], Sofian Dwi Hadiwinata[3]

[1]Department of Technology Management and Business,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA

[2]Department of Business Economics and Politics,
Universitas Muhammadiyah Kalimantan Timur, Samarinda, 75123, INDONESIA

[3]Magister of Informatics,
Universitas AMIKOM Yogyakarta, Yogyakarta 55283, INDONESIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijscet.2023.14.05.023
Received 17 November 2022; Accepted 27 July 2023; Available online 31 October 2023

Abstract: Applying Value Stream Mapping (VSM) in the mining industry can increase productivity in production process activities. The coal mining industry has a vital role in life and is an essential investment in the regional economy. However, since 2017, coal production has experienced instability based on data from the Central Bureau of Statistics for East Kalimantan Province (2021) and has yet to meet consumer demand. Previous studies have only shed light on the critical theory that VSM has extended to many industries. However, those studies need to explain the concept of applying VSM to the mining industry. Therefore, to support this theory, a case study from the mining industry was conducted to determine cycle times and identify value-adding and non-value-adding activities. A current state map is developed after making the necessary observations and calculations. Different improvement proposals are identified, and a future state map for the industry is constructed. As a result, a 23.4% reduction in cycle time and 56.1% reduction in lead time ensure its applicability in the mining industry to increase productivity and meet customer demands. VSM is a powerful tool that helps mining managers and operators identify waste and opportunities for improvement. Efficiency is one of the most important things to consider in this industry. This study is especially true in the coal mining sector.

Keywords: Lean mining, process activity mapping, value stream mapping, current state map, future state map, waste identification

1. Introduction

Indonesia is one of the World's largest coal-producing countries. In addition, based on BP statistics, the World's energy review (2021) is the World's second-largest coal exporter (Looney, 2021). East Kalimantan has the most significant resources and reserves of 70,642.52 million tons (Adi Cahyono et al., 2020). In addition, East Kalimantan's Gross Regional Domestic Product (GDP) in 2020 contributed up to 41.43 per cent (Juriana S & Anggara W, 2020). This record shows that the coal mining industry is the most important in East Kalimantan's economy. As a result, coal mining continues to concentrate on increasing production.

*Corresponding author: menik.yunie@gmail.com

However, since 2017, coal production has experienced instability based on data from the Central Bureau of Statistics for East Kalimantan Province (2021) and has failed to meet consumer demand (Fig. 1). The sustainability of the business is impacted; thus, coal mining needs to maximize resources to boost production. A production method that fully contributes to productive activities related to added value (VA) can increase productivity (Dinesh et al., 2022). Furthermore, wasteful or non-value-added (NVA) activities are the root of inefficient industrial processes (Baby et al., 2018).

Lean production techniques are needed to support these operations. Lean is a systematic approach that uses several improvement techniques to eliminate waste (Kundgol et al., 2019). The lean tool used to map the entire flow of information and material and identify waste is Value Streaming Mapping (VSM) (Zahraee et al., 2020)

Value Stream Mapping (VSM) is a visual method to describe a company's current situation with the flow of information, solve developing problems, and improve the situation in the future (Amin et al., 2019). According to Mertens et al. (2020), the purpose of the current situation assessment is to collect data to examine value-added (VA) and non-value-added (NVA) operations. Improvements can be made in the future (Lööw, 2019). In addition, previous research only described the critical theory of VSM that has been extended to many industries. However, the previous article did not explain the concept of implementing VSM in the mining industry (Romero & Arce, 2017).

Furthermore, the article explains that Kumar (2014) successfully applied VSM to the mining industry. However, this research only explains the application of lean principles to mining. Therefore, this study focuses on applying Value Stream Mapping (VSM) methods to meet customer demands and increase coal mining production activities' productivity.

1.1 Demand for Coal and the Production Gap

Demand for coal in 2020 continues to increase, with an average monthly demand of 22,741.83 tons. However, coal production only reached 20,359.75 tons on average per month (figure 1). The causes of the non-fulfillment of production targets often face problems such as scheduling delays, product quality declines, equipment damage, and human resource control (Khaba et al., 2021).

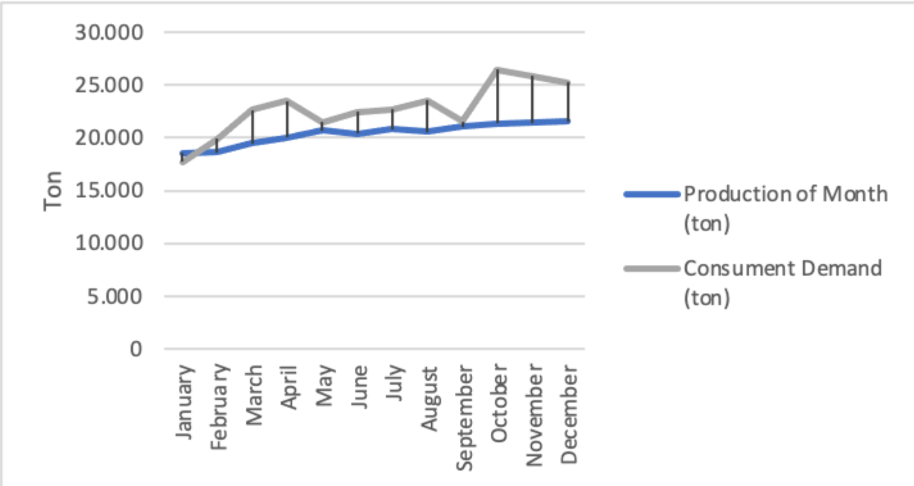

Fig. 1 - Gap Demand and Produced

Source : Coal mining industry in Samarinda, East Kalimantan Province, 2020

Eight categories of waste have been identified in the mining industry: overproduction, waiting, transportation, overprocessing, inventory, unnecessary motion, defects, and people (N. P. Kumar, 2014a; Seifullina et al., 2018). Therefore, this paper attempts to eliminate waste in the coal production process.

1.2 Coal Production Process Flow

The coal production process flow is a process that includes steps from product input to the output stage (figure 2). The first stage of coal production is receiving, or the receipt of, orders received via email, which will be negotiated, and then an MoU will be made indicating an agreement. After that, the procurement of heavy equipment will be carried out in preparation for mining exploration. The exploration process starts with land clearing, topsoil removal, stripping of overburden, stockpiling of overburden, coal cleaning, coal getting, coal transportation, crushing, stockpiling, and coal barging. Then the subsequent delivery is transshipment to the mother vessel.

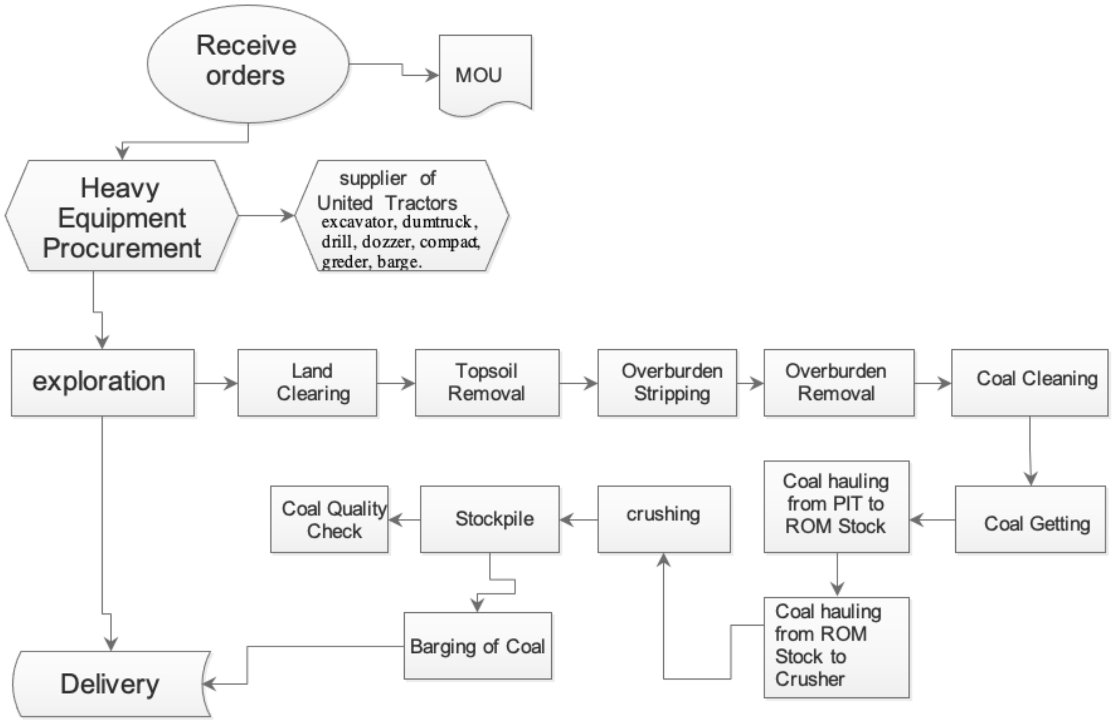

Fig. 2 - Coal Production Process Flow

The exploring phase is a step in the coal-getting process. As a result, the calculation used to create the current condition map is based on this process.

2. Lean Mining

The mining sector is similar to other industries needing boosting output and eliminating waste. The key driver behind mining's opening to the lean concept is the high degree of task complexity. Therefore, Lean Mining emphasises results and transforms the workplace culture, which will help produce successful outcomes.

Suyanto & Noya (2017) explain the lean approach as a continuous improvement technique for identifying and eliminating waste or activities that do not provide value. Lean is also a set of tools that eliminate waste, accelerate production, and raise quality (Azizi & a/p Manoharan, 2015; Jacobs & Chase, 2014; Lonnie Wilson, 2010)

As stated in the lean philosophy, the fundamental objective of lean is 1) Cost reduction through waste elimination in the manufacturing process. 2) Reduce the cost of equipment, materials, and labour. 3) Improving people's development and utilisation. This approach can streamline manufacturing, service industries, and mining waste. (S. Kumar et al., 2018; Mostafa et al., 2015; Wickramasinghe & Wickramasinghe, 2017).

According to Khaba et al. (2021), lean mining can increase the productivity and performance of the mining industry. Although it, the capacity of lean in mining to produce real business gains continuously is also stated by (Makumbe et al., 2018). This study may be seen in US and Canadian mines, where lean implementation can result in significant changes in work patterns, demonstrating that mines are comfortable with the concept (Lööw, 2019).

3. Value Stream Mapping in Mining

Value Stream Mapping (VSM) is a lean tool companies use to examine the flow of materials and information from the start of production to the finished product. Primarily used to analyze, implement, and maintain a lean approach. The goal of VSM is to identify opportunities for improvement and eliminate waste in production processes.

According to Martin & Osterling (2014), the term "value stream" was coined by James Womack, Daniel Jones, and Daniel Roos in the book that launched the Lean movement, The Machine that Changed the World (1990) and further popularized by James Womack and Daniel Jones in Lean Thinking (1996). Value stream mapping (VSM) is a technique developed by Toyota and popularized by Rother and Shook in their 1998 book Learning to See (The Lean Enterprise Institute). VSM is an essential component of every activity. It provides a detailed understanding of the current state by clarifying flows and using detractors to smooth them (Jimmerson, 2010; King & King, 2015; Nash & Poling, 2008).

Furthermore, VSM maps material flows described as all actions, whether value-added (VA) or non-value-added (NVA), that can eliminate waste, reduce waiting times, and lower costs to optimize production processes. (Mudgal et al., 2020a). Masuti and Dabade (2019) say that the current condition map has standard icons for future state maps. (Faridah & Lestari, 2016; Ghushe et al., 2017; Keyte & Locher, 2016; Lacerda et al., 2016; Rohani & Zahraee, 2015; Setiawan et al., 2021; Singh et al., 2011; Stadnicka & Ratnayake, 2016; Zahraee et al., 2020) explains that this approach is not limited to the automotive and service industries. Furthermore, according to Romero (2017), in a literature article, VSM can also be used in the mining sector.

In the mining industry, Value Stream Mapping can be crucial in optimizing operations and improving overall efficiency. Mining involves a complex value chain, from exploration and site development to mineral extraction, processing, and transportation. VSM can help in the following ways (William & Fazleena, 2014):

1. **Identifying inefficiencies:** Value Stream Mapping allows mining companies to identify bottlenecks, redundancies, and waste. By visualizing the entire process, they can pinpoint areas where resources and time are underutilized.
2. **Improving flow:** VSM helps streamline the flow of materials, information, and processes, thus reducing lead times and cycle times. This flow, in turn, can lead to faster production and improved customer response times.
3. **Waste reduction:** The mining industry can be resource-intensive and generate substantial waste. Value Stream Mapping helps identify non-value-adding activities and waste, such as overproduction, excess inventory, and unnecessary transportation, which can be targeted for elimination.
4. **Enhancing safety:** Mapping out the entire value stream can also highlight potential safety hazards and risks, allowing companies to implement measures to improve the safety of their operations.
5. **Supporting continuous improvement:** Value Stream Mapping is not a one-time exercise. It forms the basis for continuous improvement efforts, encouraging mining companies to regularly reassess and optimize their processes as conditions and requirements change.
6. **Collaboration and communication:** VSM promotes cross-functional collaboration and communication by involving various stakeholders from different departments in the mapping process. This fosters a shared understanding of the value stream and encourages teamwork towards common improvement goals.

In conclusion, Value Stream Mapping is a valuable tool for the mining industry to optimize operations, eliminate waste, and enhance overall efficiency. By visualizing the entire value chain and identifying areas for improvement, mining companies can work towards becoming more competitive, sustainable, and responsive to customer demands.

4. Methodology

4.1 Application Areas and A Concept of A Value Stream Mapping Approach Implementation

The VSM technique was applied in the coal mining industry East Kalimantan Province, to eliminate waste that is not value-added in the coal production process. Coal production continues to be below consumer demand (fig. 1). There are various problems, such as delivery delays often occur in the heavy equipment procurement process, high incidence of accidents in the transportation process, sudden burning of coal in the stockpile, and sometimes a reduction in the number of cargo processing loads that are not under the storage plan, thus making production not reach the target and the length of the completion process have an impact on the high cost of production. Table 1 describes the outline of the VSM implementation carried out.

Table 1 - A description of the VSM technique's implementation

Steps	Task
1	Identify the coal production process by looking at the process flow, number of operators, machine usage, and processing time.
2	Make a current state VSM that details the procedure with the steps, delays, and information flowing as at the time.
3	Evaluate the current VSM to create flow by removing waste, particularly unneeded NVA waste.
4	Create a future state VSM
5	Implement future state VSM

4.2 Waste Identification

The Toyota Production System (TPS) defines "waste" objectively using a core concept known as "the seven wastes." But as per (Seifullina et al., 2018), the mining industry produces eight wastes:

1. Overproduction: The mining industry and TPS view overproduction as waste. Overproduction in the context of coal mining refers to mining or processing more coal than is required for immediate usage or customer demand. This overproduction can result in unneeded inventory accumulation, the sapping of important resources, and, eventually, higher costs and inefficiencies.

2. Transportation: TPS and the mining industry identify wasteful transportation as waste. This waste occurs when transporting supplies, machinery, or coal-related products farther than is necessary. Excessive transportation can cause delays and inefficiencies in production by using up time and resources.

3. Inventory: Both the mining industry and TPS view inventory as a waste. Inventory waste in the coal mining industry is the surplus of coal products or raw resources. Excessive inventory ties up operating capital, takes up valuable space and could cause the coal that is being stored to deteriorate or become obsolete.

4. Motion: TPS and the mining industry know the waste of motion. Motion waste can happen throughout coal mining due to excessive worker or equipment movement. Such motion waste can be identified and reduced to increase efficiency and safety.

5. Defects: The mining industry and TPS view defects as waste. Defects in the extraction and processing of coal might appear as subpar coal products or as mistakes. Faults must be reduced to preserve product quality, lower rework, and boost overall efficiency.

6. Overprocessing: TPS and the mining industry identify overprocessing as a waste. When too many resources or stages are used in the production process in coal mining, overprocessing waste can happen, resulting in inefficiencies and higher prices.

7. Waiting: TPS and the mining industry consider waiting for waste. Waiting for waste in the coal mining industry refers to downtime that personnel, machinery, or supplies endure during production. A mining operation can become more efficient and responsive by reducing waiting times.

8. People: According to Seifullina et al. (2018), "people" is one of the wastes in the mining industry. The underutilization or improper allocation of human resources, a lack of training, or ineffective work methods are all examples of "waste of people" in this context. Getting rid of this waste can improve employee engagement, skill development, and productivity.

These detected wastes closely match the waste kinds defined by TPS in our study on implementing VSM in the coal mining industry. We focused on reducing these wastes through VSM to improve productivity, streamline production processes, and decrease inefficiencies. We significantly reduced cycle time and lead time, as shown in the study's results, by detecting and getting rid of these wastes.

The similarity in the waste kinds recognized by TPS and Seifullina et al. (2018) and their correlation highlights the applicability and universality of waste reduction principles in various industries, including the mining industry. We showed how the mining industry might gain from systematically identifying and eliminating waste to increase efficiency and production by using VSM and addressing these wastes in the coal mining process.

Table 2 - Lean's 8 wastes in the mining sector

Wastes	Description
1. Waiting	Unsuitable working conditions or the environment are to blame for this waste.
2. Transportation	Inefficient transportation design and excessive stages result in wasted transportation.
3. Overproduction	without understanding the purpose, sustainable production has more capacity than is required.
4. Motion	excessive job variety and ineffective equipment use.
5. Defects	product damage and equipment damage all result in defective waste.
6. Overprocessing	Too many steps redundant, one operator doing some work more than one
7. Inventory	Inefficient inventory management on stockpile
8. People	Unskilled labor, absenteeism, assigning the wrong person to a task, inappropriate communication.

4.3 Mapping the Current State

Current State Map (CSM) provides a detailed visual picture of the current state of the coal mining industry's production process (Fig. 3). It provides stakeholders with insights into the current workflow. It identifies opportunities for improvement by illuminating the information flow and operations involved in the mining process.

Based on Karim et al., (2012) Significant Elements of the Current State Map :

1. Process Flow: The CSM illustrates how the various steps in the coal mining process are carried out. Each activity is denoted by a unique symbol, such as a rectangle for a phase in the process, a diamond for a choice, or an arrow for moving materials or information. Maps can depict events in chronological order to understand information and materials going through the production process.

2. Value-Adding and Non-Value-Adding Activities: The CSM distinguishes between these activities. While non-value-adding operations do not add any value to the finished product, value-adding activities directly contribute to the manufacture of coal products. It is simple to spot areas of waste and inefficiency when coloured symbols or notes indicate the nature of the action.

3. Wait Times and Delays: Any wait times or delays that arise during the production process are highlighted by the CSM. These could happen due to slow-moving traffic, process bottlenecks, etc. The length of wait times is indicated by arrows or notes, which aid in understanding how delays affect the total production schedule.

4. Inventory Points: Raw materials or coal products are held in inventory points on the CSM. These locations show where inventory accumulates throughout production, possibly leading to waste and sapping essential resources.

5. Decision Points and Information Flow: Diamond-shaped decision points, which stand in for crucial decisions in the production process, are used to denote these locations. The information flow, represented by arrows or lines, illustrates how information is shared and used across the mining operation.

6. Data and Metrics: Pertinent data and metrics are incorporated into the CSM to offer quantitative insights into the production process. To comprehend the current performance of the mining operation, cycle times, lead times, production volumes, and other key performance indicators (KPIs) may be displayed alongside the process flow.

4.4 Process Activity Mapping (PAM)

All production activities are mapped into a table and categorised according to nature. As a result, it is possible to distinguish between value-added (VA), non-value-added (NVA), and necessary but non-value-added (NNVA) operations (Shou et al., 2020). The future state map can be improved by eliminating activities that don't provide value.

A detailed breakdown of the production activities mapped through the Value Stream Mapping (VSM) procedure in the coal mining industry is shown in Table 3. Each activity has a unique Activity Code and a thorough description. In addition, the activities are divided into three groups according to add value to the value stream:

1. Value-Adding (VA) Activities: These actions directly improve the final coal product's value and meet the needs and preferences of the client. Value-Adding activities in the coal mining sector include coal extraction, processing, shipment preparation, and customer order fulfilment. These operations are critical to the core production process to meet consumer requests.

2. Non-Value-Adding (NVA) Activities: These actions are waste since they don't improve the ultimate result. Quality inspection, coal storage, and internal documentation are examples of non-value-adding tasks that may be performed in the coal mining sector. Although some of these tasks may be required for internal procedures or regulatory compliance, they may not directly contribute to the client's needs. They can be targeted for deletion or optimisation in the future state map.

3. Necessary but non-value-adding (NNVA) activities are required for the production process but do not directly enhance the value of the finished good. Transportation of coal to processing facilities and equipment maintenance are examples of necessary but non-value-adding tasks in the coal mining sector. Although these tasks are crucial for streamlining the main manufacturing process, they have no direct bearing on the client's needs. In the Future State Map, efforts can be taken to optimise and lessen inefficiencies related to these tasks.

The Future State Map's growth depends heavily on categorising the activities in Table 3. (FSM). Stakeholders can concentrate their improvement efforts on streamlining waste reduction and production processes by clearly defining Value-Adding, Non-Value-Adding, and Necessary but not Value-Adding activities.

Activities labelled Non-Value-Adding in the Future State Map might be targeted for deletion or process optimisation to eliminate inefficiencies. The production process can be made more efficient by eliminating or improving these steps, which reduces cycle time, lead time, and waste in general.

Additionally, identifying actions that are necessary but do not add value enables stakeholders to look into options for process improvement. The utilisation of resources may be improved, and the production process can become more responsive and agile by increasing the efficiency of these tasks.

Stakeholders use Table 3's Activity Classification as a crucial resource while creating the Future State Map (FSM). It enables data-driven decision-making and guarantees that efforts to improve the coal mining production process are focused on reducing waste and boosting the total value stream.

4.5 Mapping the Future State

The expected enhancements and optimizations done to increase productivity in the coal mining industry are illustrated in Future State Map (FSM). After considering the suggested modifications found in the Value Stream Mapping (VSM) analysis of the existing circumstances, it displays the manufacturing process's intended state.

By directly addressing non-value-adding operations, the proposed solutions immediately address waste in the production process, as shown by the FSM (Fig.4). By doing this, the mining operation is made more productive overall, resource consumption is optimized, and efficiency is increased.

The quantitative evaluation of the anticipated benefits is made easier by including data and indicators on the FSM. Stakeholders can verify the possible advantages of the suggested improvements and establish goals for the expected performance in the future by comparing the FSM data with the data on the current state.

The FSM also offers a timeline for putting the suggested modifications into action. As the improvements are gradually implemented, it acts as a roadmap for stakeholders to coordinate their efforts and monitor success.

In general, Figure 4: Future State Map (FSM) provides a useful tool to understand the anticipated enhancements and optimizations in coal mining production. It helps stakeholders understand the predicted increases in productivity and directs them on their route to achieving operational excellence and better meeting customer requests.

5. Results

5.1 The Making of The Current State Map (CSM)

The flow of the coal production process served as the basis for the creation and visual organization of the existing state VSM. A high-level overview of the mining and processing of coal is shown in Figure 2, along with a list of the important steps. It is a starting point for comprehending how mining operations progress from extraction through customer order fulfilment.

In Figure 3, the Current State Value Stream Map (VSM), which builds on Figure 2, the production activities involved in each stage of the coal production process are graphically organized and described. The VSM provides stakeholders with a visual representation of the flow of activities, information, and materials so they can spot waste and inefficiencies in the existing production process.

Stakeholders can learn more about the current state of the coal-producing process by analyzing the Current State VSM. They can spot non-value-adding processes and areas for improvement to boost output, shorten turnaround times, and maximize resource efficiency. The Future State Map (FSM), which incorporates suggested enhancements and optimizations to optimize the production process and advance toward operational excellence, is developed using the VSM as a powerful instrument for direction.

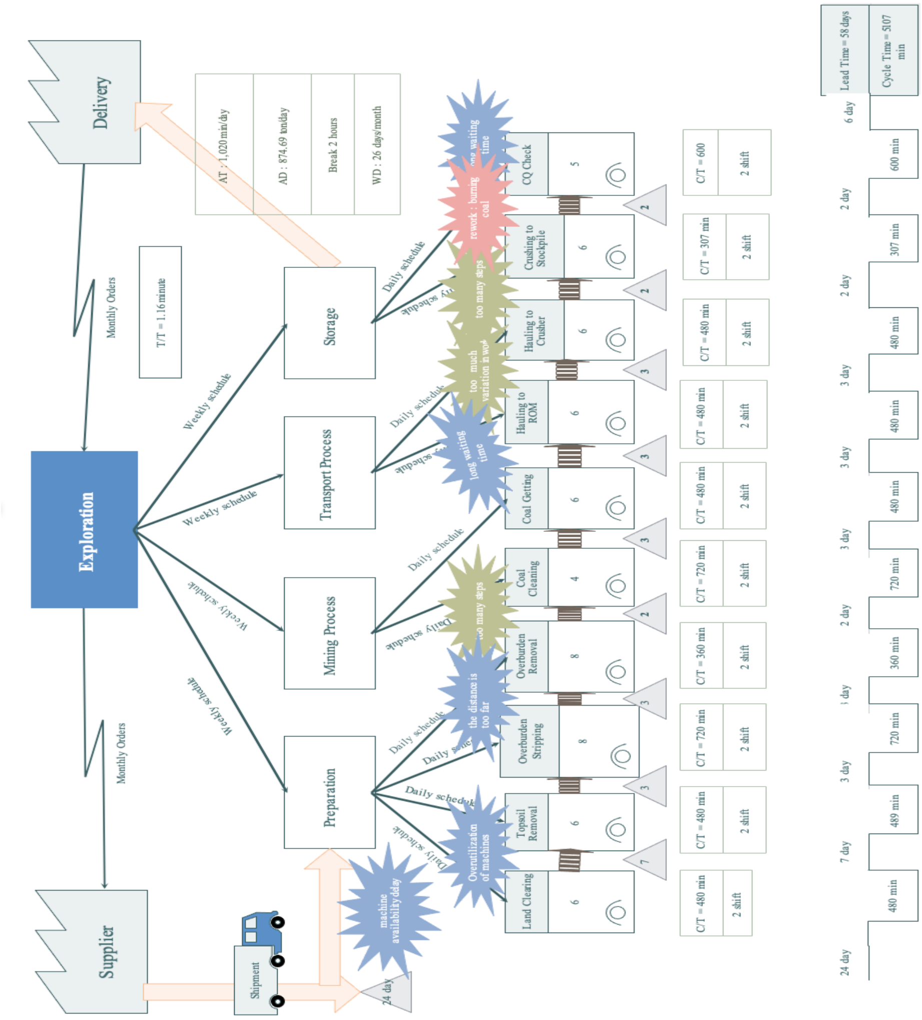

Fig. 3 - Current state map of coal production

5.2 Process Activity Mapping (PAM)

Process activity mapping provides an overview of the physical flow, information flow, and time allotted for each activity; the number of operators, and the distance travelled. The activity category consists of value-added (VA), necessary but non-value-added (NNVA), and non-value-added (NVA) and must be eliminated. In making process activity mapping, there are five types of activities consisting of operation (O), transportation (T), inspection (I), delay (D), and storage (S). The activity mapping process is in Table 3 below.

Table 3 - Process activity mapping of the coal production

No.	Process	Code	Activity	Machine / Tools	Activity Type	Man power	Time Process (Minute)	Category (VA. NVA. NNVA)
1	Procurement	PO1	Order coal mining equipment at United Tractor (UT)	excavator, bulldozer, backhoe, drill, dumptruck	O	1	1.440	VA
		PO2	Awaiting the availability of a mining machine		D		28.800	NVA
		PO3	Machine checking process	excavator, bulldozer, backhoe, drill, dumptruck	I	5	2.880	NVA
		PO4	Machine sent to the mine site	excavator, bulldozer, backhoe, drill, dumptruck	T		1.440	NNVA
2	Preparation	PE1	Land clearing	excavator, Bulldozer	O	4	10.080	NNVA
		PE2	Topsoil removal	Excavator, dumtruck	T	6	4.320	NNVA
		PE3	Overburden stripping	Drill, blasting	O	8	4.320	VA
		PE4	Overburden removal	Backhoe, dumtruck	T	6	2.880	NNVA
3	Mining Process	MP1	Coal cleaning	Excavator with cutting blade	I	2	4.320	NVA
		MP2	Coal getting to loading	Excavator, dumtruck	O	6	4.320	VA
4	Transport Process	TP1	Coal hauling from pit to ROM stock	dumtruck	T	6	4.320	NNVA
		TP2	Coal hauling from ROM stock to crusher	dumtruck	T	4	2.880	NVA
5	Storage	ST1	Crushing process to stockpile	crusher	S	6	2.880	NNVA
		ST2	Coal quality check	Lab	I	5	600	NNVA
6	Delivery	DE1	Coal transfer	conveyor,	T			NNVA

		from stockpile to barge	dumptruck		12	4.320	
	DE2	Transhipment process to mother vasel	barge	T	6	4.320	NNVA
Total (∑)					77	84.120	

Based on the table, the following types of activities have been recognized in the coal-producing process:

1. Operations: 4 activities fall under this category. These actions involve fundamental production procedures that directly support coal extraction and processing. Coal extraction, processing, shipping preparation, and order fulfilment are all possible operations in the coal mining sector.

2. Transportation: Seven activities fall under this category. These tasks entail moving supplies or coal-related goods around the manufacturing process from one place to another. Transportation tasks could involve moving coal from the mining site to the processing facility, moving coal between processing steps, or delivering coal products to customers or storage.

3. Inspection: Three different actions fall under the inspection category. These activities involve quality control and inspection procedures to ensure the generated coal fulfils the necessary quality requirements. Examining the quality of the coal after processing and doing quality checks before shipping it to consumers are examples of quality inspection activities.

4. Delay: One activity is categorized as a delay. This activity represents the waiting or idle time that happens during the production process. Equipment failure, a lack of resources, or logistical problems are a few causes of delays.

5. Storage: One activity is categorized as storage. After processing, this activity includes keeping and storing coal products in specified storage areas. Storage is necessary to control inventories and enable prompt client delivery.

The total processing time, or 84.120 minutes, is the entire amount of time needed to finish all tasks involved in producing coal. It considers all wait times, process delays, the processing time for each activity, travel time between activities, and any wait times.

Overall, the activity breakdown and overall processing time offer useful quantitative insights into the current state of the coal production process. Stakeholders can identify areas for improvement and focus on particular activities for optimization to increase productivity and decrease inefficiencies by understanding the types of activities and their associated durations. The Current State Value Stream Map (VSM) is crucial in helping stakeholders visualize this data, build the Future State Map (FSM), and put the suggested changes into practice for a more effective and streamlined coal mining production process. As a result, Table 4 below shows the data that was obtained.

Table 4 - The Type of Activities that Provide Added Value

Category	Activitys	Time (minute)	Percentage (%)
Operation	4	20.160	23.97
Transportation	7	24.480	29.10
Inspection	3	7.800	9.27
Delay	1	28.800	34.24
Storage	1	2.880	3.42
Total	16	84.120	100%
Value Added (VA)	3	10.080	11.98
Non Value Added (NVA)	4	38.880	46.22
Necessary Non Value Added (NNVA)	9	35.160	41.80
Total	16	84.120	100%

Actions that do not add value but are necessary (NNVA) dominate the coal-producing activities. As a result, while this activity cannot be removed entirely, it can minimize the production process's time. Furthermore, non-value-added activities (NVA) can be eliminated. Activities that add value (VA) can therefore be optimized.

5.3 Waste Identification

The following is a list of wastes identified based on the current state map and scheduled activities as an improvement process in the future state map. Activities for producing coal with improvement phases are shown in table 5.

Table 5 - Activities to improve the coal production process

No	Before	After
1	Procurement	
	Purchase of coal mining equipment with United Tractor (UT) is carried out with a Pre Order (PO) system	Collaborating with several vendors with a ready stock system
2	Waiting for the availability of mining machines sent from Jakarta	Heavy machinery can be sent directly to the mine site
3	Twice the machine inspection process was carried out; at the UT office and at the mine site	Machine inspection can be done once when the machine is received
4	Heavy equipment delivery is done by land route.	To shorten the delivery time can use the river route and reduce the risk of damage to heavy machinery
5	Land clearing	
	Land clearing of 10ha is only done with two heavy machinery	Land clearing can be focused on reducing waiting time by increasing the use of machines and operators so that it is quickly resolved
6	Topsoil removal	
	The soil layer is moved to the bunker with a distance of 15 km	The bunker layout should not exceed 10 km.
7	Stripping overburden	
	Preparing explosives, ensuring spare parts, drilling work to insert explosives, blasting and hauling	Avoid work accidents; signs are observed, tighten the application of standard operating procedures
8	Overburden removal	
	material is transported to be moved to the disposal site with a distance of 900 meters	Exhaust distance of 550 meters is enough
9	Coal cleaning	
	Material cleaning before coal extraction	This process can be omitted because it has been carried out at the time of overburden removal.
10	Coal getting	
	Coal extraction using an excavator	The condition of the machine can be given more attention so that activities run smoothly.

11	Coal hauling from PIT to ROM stock	It can be whittled down to one stage in this activity. The coal from the ROM stock is ultimately taken to the crusher for stockpile storage.
12	Coal hauling from ROM stock to crusher	Storage layout on the stockpile is 4.5 meters with a volume of 7,400 m^3
13	Crushing process to stockpile	It is necessary to ensure that the crusher is not hampered in this process
14	Coal quality check	Sampling collection is carried out every five hours, after which it will be tested in the laboratory
15	Delivery	Coal shipped using the FIFO method

5.4 Future State Map

A future state map is a proposed improvement of the current state map by eliminating activities considered waste or no added value (NVA). The following is the Future State Map in Figure 4. below.

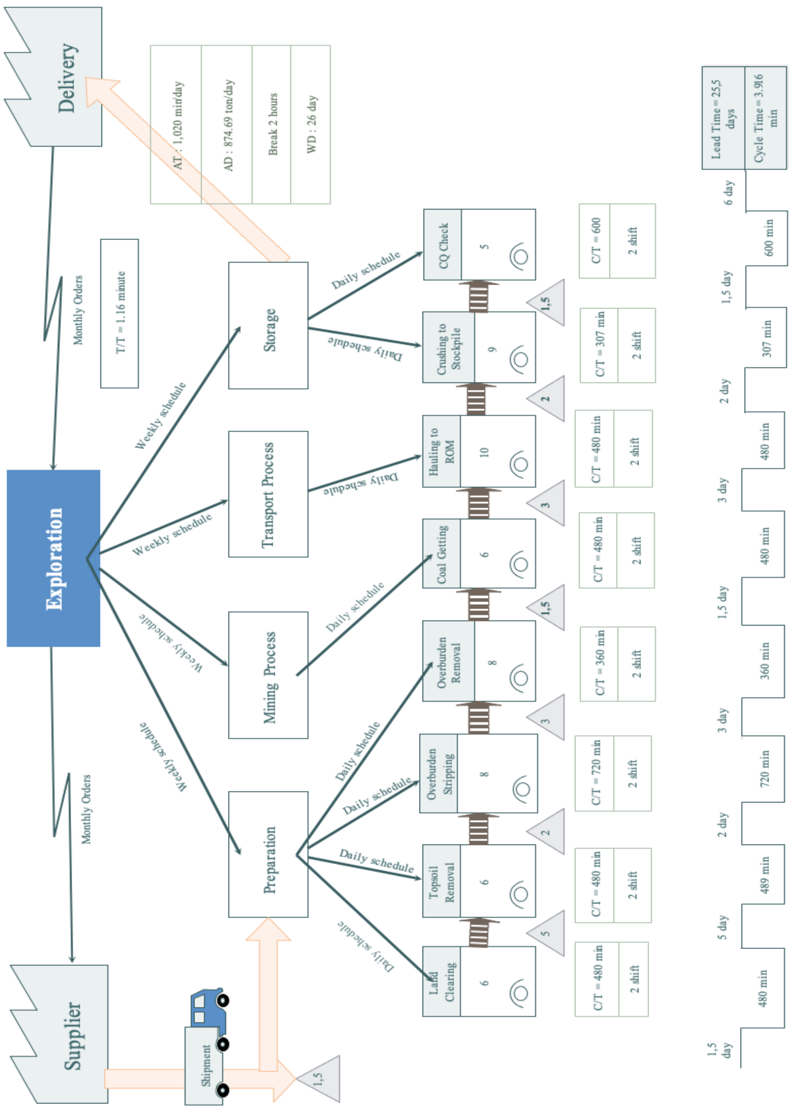

Fig. 4 - Future state map of coal production

As a result of eliminating non-value-added operations (NVA) and reducing processing time (NNVA), the coal production process time was 37,140 minutes.

5.5 Process Cycle Efficiency (PCE)

Process Cycle Time (PCE) is one sign of how well a process works. In PCE, Value Add (VA) and Total Lead Time are compared. When the PCE value is ≥30, the process may be seen as having adopted the lean philosophy or being more productive. The following is a comparison of the cycle time process against the current state VSM with the future state VSM (Fig. 5)

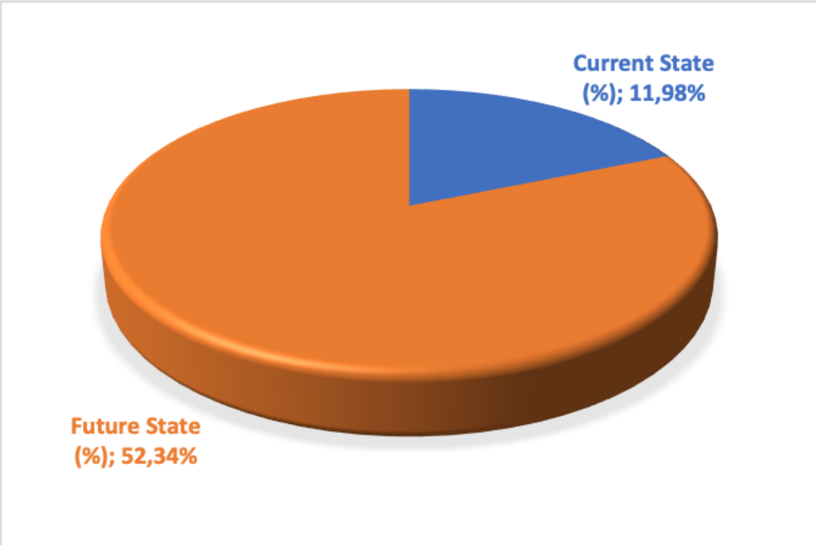

Fig. 5 - PCE Current State vs. Future State

Based on the comparison results of the current state PCE, which is 11.98 percent and the future state PCE is 52.34 percent, there are differences in the proportion of coal mining activities, which indicates that using the value stream mapping method can reduce activities that do not provide value for benefits and wasteful activities to encourage increased work to become more efficient and effective to give results the best to customers regarding the fulfillment of coal mining production demands.

6. Discussion

VSM determines the current state of qualitative analysis in the manufacturing process. The current state depicts a map containing information about the current production process to facilitate the identification of the waste generated in the process (Kundgol et al., 2019; Lugert et al., 2018; Manjunath et al., 2014; Mertens et al., 2020; Mudgal et al., 2020b; Pathania et al., 2021). The results of this study indicate that the average production (AP) is 20,359.75 tons/month, and the average demand (AD) is 22,741.83 tons/month. The production process time is 84,120 minutes, and the cycle time is 5,107 minutes. Furthermore, takt time is 1.16 minutes with an available time (AT) of 1,020 minutes per day.

Furthermore, the activity mapping process results show that the current production process has 3 VA with a presentation of 11.98%, NVA with a presentation of 46.22%, and NNVA with a presentation of 41.80%. So it is necessary to optimize VA, minimize NNVA, and eliminate NVA.

As a result, the comparison of the current state's process cycle time (PCE) is 11.98%, and the future state is 52.34%. Thus, this process could have adopted a lean philosophy or been more productive. Another finding in the future state is that the lead time (LT) is 37,140 minutes, and the cycle time (CT) is 3,916 minutes. So, it can be seen that there is a significant time reduction in the coal production process.

7. Conclusions

The VSM tool is used to analyze the current state of the coal production process and its prospects in the future. The application of VSM is carried out as an identification of waste, namely activities that do not provide added value (NVA), activities that are needed but do not provide value (NNVA), and activities that provide added value (VA), which can be optimized.

As a result, based on the future state map going forward, as a result of the improvement process, PCE increased from 11.98 percent to 52.34 percent. Thus, the production process can be categorized as having adopted lean principles and can be said to be more productive. In addition, the average production only reached 20,359.75 tons/month of coal demand, which was 22,741.83 tons/month. Based on the improvement process results, the lead time was reduced from 84,120 minutes to 37,140 minutes, with 26 working days available in a month. So, the average production is 26,380.65 tons, which means that the mining industry can meet consumer demand.

The research results can help mine managers and operators gain knowledge about updating production processes by implementing VSM to increase productivity and meet customer demands. In addition, efficiency is an essential issue in the mining sector. So, this shows that the application of the VSM concept also applies to the coal mining sector.

Acknowledgement

The authors would like to thank the leadership of PT. Citra Dayak Indah for providing the opportunity to conduct this research. The authors are also grateful to the Chancellor of the Universitas Muhammadiyah Kalimantan Timur, who continues to support this research, and the author thanks the supervisor of the Universiti Tun Hussein Onn Malaysia, who has guided this research.

References

A. Karim, A. Jaafar, M. Abdullah, M. Haque, Yeakub Ali Mohammad, S.A. Azline. (2012). Applying Value Stream Mapping for Productivity Improvement of a Metal Stamping Industry. *Publisher in Materials Science and Engineering*. Advanced Materials Research Vol. 576. https://doi.org/10.4028/www.scientific.net/AMR.576.727

Adi Cahyono, A., Lasnawatin, F., Prananto Budi, A., & Hakim, L. (2020). Hanbook of Energy & Economics Statistics of Indonesia. *Ministry of Energy and Mineral Resources Republic of Indonesia*.

Amin, A. N. M., Wan Mahmood, W. H., Kamat, S. R., & Kamalrudin, M. (2019). Continuous improvement through lean using VSM for application in machining based product company. *International Journal of Recent Technology and Engineering*, *8*(2 Special Issue 11), 778–784. https://doi.org/10.35940/ijrte.B1127.0982S1119

Andryanto, A., & Vanany, I. (2020). Application of Value Stream Mapping on Operating Project Business Process at Nickel Mining Industry. *IPTEK Proceedings The 6th International Seminar on Science and Technology*, *6*.

Azizi, A., & a/p Manoharan, T. (2015). Designing a Future Value Stream Mapping to Reduce Lead Time Using SMED-A Case Study. *Procedia Manufacturing*, *2*(February), 153–158. https://doi.org/10.1016/j.promfg.2015.07.027

Baby, B., Prasanth, N., & Selwyn Jebadurai, D. (2018). Implementation of Lean Principles To Improve the Operations of. *International Journal of Technology*, *1*, 46–54.

Dinesh, S. N., Shalini, M., Vijay, M., Vijey Mohan, R. C., Saminathan, R., & Subbiah, R. (2022). Improving the productivity in carton manufacturing industry using value stream mapping (VSM). *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2022.05.015

Faridah, C., & Lestari, Y. D. (2016). Time Waste Identification Using Value Stream Mapping in Wood Manufacturing. *Journal Of Business And Management*, *5*(1), 118–127.

Ghushe, S., Deshmukh, S., Basgoti, V., Yawale, Y., & Gangasagar, P. (2017). Implementation of Value Stream Mapping (VSM) in a Coir Product Manufacturing Industry. *International Research Journal of Engineering and Technology (IRJET)*, *04*(04), 457–462. www.irjet.net

Jacobs, F. R., & Chase, R. B. (2014). *Operations and Supply Chain Management* (Kaylee Putbrese, Ed.; Fourteenth). McGraw - Hill Companies, Inc.

Jimmerson, C. (2010). *Value Stream Mapping for Healtcare Made Easy*. Taylor & Francis. http://www.taylorandfrancis.com

Juriana S, K., & Anggara W, A. (2020). GROSS REGIONAL DOMESTIC PRODUCT OF KALIMANTAN TIMUR PROVINCEBY INDUSTRY 2016-2020. *Badan Pusat Statistik Provinsi Kalimantan Timur*.

Kęsek, M., Bogacz, P., & Migza, M. (2019). The application of Lean Management and Six Sigma tools in global mining enterprises. *IOP Conference Series: Earth and Environmental Science*, *214*(1). https://doi.org/10.1088/1755-1315/214/1/012090

Keyte, B., & Locher, D. A. (2016). *The Complete Lean Enterprise : Value Stream Mapping for Office and Services* (Second Edi). Taylor & Francis Group. http://www.taylorandfrancis.com

Khaba, S., & Bhar, C. (2018). Lean awareness and potential for lean implementation in the Indian coal mining industry: An empirical study. *International Journal of Quality and Reliability Management*, *35*(6), 1215–1231. https://doi.org/10.1108/IJQRM-02-2017-0024

Khaba, S., Bhar, C., & Ray, A. (2021). A study on key lean enablers of the coal mining sector using ISM, MICMAC and SEM. *TQM Journal*, *33*(6), 1281–1305. https://doi.org/10.1108/TQM-04-2020-0069

King, P. L., & King, J. S. (2015). *Value Stream Mapping for the Process Industries*. Taylor & Francis. http://www.taylorandfrancis.com

Knoll, D., Reinhart, G., & Prüglmeier, M. (2019). Enabling value stream mapping for internal logistics using multidimensional process mining. *Expert Systems with Applications*, *124*, 130–142. https://doi.org/10.1016/j.eswa.2019.01.026

Kumar, N. P. (2014a). Analysing the Benefits of Value Stream Mapping in Mining Industry. *International Journal of Innovative Research in Science, Engineering and Technology*, *3*(10), 16668–16673. https://doi.org/10.15680/IJIRSET.2014.0310035

Kumar, N. P. (2014b). Analysing the Benefits of Value Stream Mapping in Mining Industry. *International Journal of Innovative Research in Science, Engineering and Technology*, *3*(10), 16668–16673. https://doi.org/10.15680/IJIRSET.2014.0310035

Kumar, S., Dhingra, A., & Singh, B. (2018). Lean-Kaizen implementation: A roadmap for identifying continuous improvement opportunities in Indian small and medium sized enterprise. In *Journal of Engineering, Design and Technology*. Emerald Group Publishing Ltd. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85042105788&doi=10.1108%2FJEDT-08-2017-0083&partnerID=40&md5=988b130ead0715539f0957f7cfc178ee

Kundgol, S., Petkar, P., & Gaitonde, V. N. (2019). Implementation of value stream mapping (VSM) upgrading process and productivity in aerospace manufacturing industry. *Materials Today: Proceedings*, *46*, 4640–4646. https://doi.org/10.1016/j.matpr.2020.10.282

Lacerda, A. P., Xambre, A. R., & Alvelos, H. M. (2016). Applying Value Stream Mapping to eliminate waste: A case study of an original equipment manufacturer for the automotive industry. *International Journal of Production Research*, *54*(6), 1708–1720. https://doi.org/10.1080/00207543.2015.1055349

Lonnie Wilson. (2010). *How to Implement Lean Manufacturing*. McGraw - Hill Companies, Inc.

Looney, B. (2021). *Full report – Statistical Review of World Energy 2021*.

Lööw, J. (2019). An investigation into lean production practice in mining. *International Journal of Lean Six Sigma*, *10*(1), 123–142. https://doi.org/10.1108/IJLSS-07-2017-0085

Lugert, A., Batz, A., & Winkler, H. (2018). Empirical assessment of the future adequacy of value stream mapping in manufacturing industries. *Journal of Manufacturing Technology Management*, *29*(5), 886–906. https://doi.org/10.1108/JMTM-11-2017-0236

Makumbe, S., Hattingh, T., Plint, N., & Esterhuizen, D. (2018). Effectiveness of using Learning Factories to impart Lean principles in mining employees. *Procedia Manufacturing*, *23*, 69–74. https://doi.org/10.1016/j.promfg.2018.03.163

Manjunath, M., Shivaprasad, H. C., Kumar Keerthesh, K. S., & Puthran, D. (2014). Value Stream Mapping as a Tool for Lean Implementation: A Case Study. *International Journal of Inovative Research & Development*, *3*(5), 477–481. https://doi.org/10.1108/13683040910984338

Martin, K., & Osterling, M. (2014). *Value Steam Mapping*. McGraw-Hill Education.

Masuti, P. M., & Dabade, U. A. (2019). Lean manufacturing implementation using value stream mapping at excavator manufacturing company. *Materials Today: Proceedings*, *19*, 606–610. https://doi.org/10.1016/j.matpr.2019.07.740

Mertens, K., Bernerstätter, R., & Biedermann, H. (2020). Value Stream Mapping and Process Mining: A Lean Method Supported by Data Analytics. *Conference On Production Systems and Logistics*, 119–126. https://doi.org/https://doi.org/10.15488/9653

Mostafa, S., Dumrak, J., & Soltan, H. (2015). Lean Maintenance Roadmap. In *Procedia Manufacturing*. Elsevier B.V. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85013157667&doi=10.1016%2Fj.promfg.2015.07.076&partnerID=40&md5=b172a81cf811d16ba158d9d8f659cea7

Mudgal, D., Pagone, E., & Salonitis, K. (2020a). Approach to value stream mapping for make-to-order manufacturing. *Procedia CIRP*, *93*, 826–831. https://doi.org/10.1016/j.procir.2020.04.084

Mudgal, D., Pagone, E., & Salonitis, K. (2020b). Approach to value stream mapping for make-to-order manufacturing. *Procedia CIRP*, *93*, 826–831. https://doi.org/10.1016/j.procir.2020.04.084

Nash, M. A., & Poling, S. R. (2008). *Mapping The Total Value Stream*. Taylor & Francis Group. http://www.taylorandfrancis.com

Okyere, I. O. (2016). Managing Lean Principles applicability and implementation in the mining industry in Ghana. A Review Paper on Related Literature. *Archives of Business Research*, *4*(6), 282–299. https://doi.org/10.14738/abr.46.2422

Pathania, A., Kumar, R., Rojhe, K., Goel, B., Aggarwal, S., & Mahto, D. (2021). Value stream mapping - Panacea for lead time reduction in ferrite core industry. *Materials Today: Proceedings*, *46*, 2456–2461. https://doi.org/10.1016/j.matpr.2021.01.362

Rohani, J. M., & Zahraee, S. M. (2015). Production Line Analysis via Value Stream Mapping: A Lean Manufacturing Process of Color Industry. *Procedia Manufacturing*, *2*(February), 6–10. https://doi.org/10.1016/j.promfg.2015.07.002

Romero, L. F., & Arce, A. (2017). Applying Value Stream Mapping in Manufacturing: A Systematic Literature Review. *IFAC-PapersOnLine*, *50*(1), 1075–1086. https://doi.org/10.1016/j.ifacol.2017.08.385

Rosienkiewicz, M. (2012). Idea of adaptation value stream mapping method to the conditions of the mining industry. *AGH Journal of Mining and Geoengineering*, *36*(3), 301–307. https://doi.org/10.7494/mining.2012.36.3.301

Seifullina, A., Er, A., Nadeem, S. P., Garza-Reyes, J. A., & Kumar, V. (2018). *A Lean Implementation Framework for the Mining Industry*. *51*(11), 1149–1154. https://doi.org/10.1016/j.ifacol.2018.08.435

Setiawan, I., Tumanggor, O. S. P., & Purba, H. H. (2021). Value Stream Mapping: Literature Review and Implications for Service Industry. *Jurnal Sistem Teknik Industri*, *53*(5–8), 155–156. https://doi.org/https://doi.org/10.32734/jsti.v23i2.6038

Singh, B., Garg, S. K., & Sharma, S. K. (2011). Value stream mapping: Literature review and implications for Indian industry. *International Journal of Advanced Manufacturing Technology*, *53*(5–8), 799–809. https://doi.org/10.1007/s00170-010-2860-7

Stadnicka, D., & Ratnayake, R. M. C. (2016). Minimization of service disturbance: VSM based case study in telecommunication industry. *IFAC-PapersOnLine*, *49*(12), 255–260. https://doi.org/10.1016/j.ifacol.2016.07.609

Suyanto, D. A., & Noya, S. (2017). Waste Elimination Using Value Stream Mapping and Valsat. *Jurnal Ilmiah Teknik Industri*, *3*(2), 110–117. https://doi.org/10.24912/jitiuntar.v3i2.501

W. Shou, Jun Wang, Peng Wu, Xiangyu Wang. (2020). Value adding and non-value adding activities in turnaround maintenance process: classification, validation, and benefits. *Production planning & control (Print)*. The Management of Operations Volume 3. https://doi.org/10.1080/09537287.2019.1629038

Wickramasinghe, G. L. D., & Wickramasinghe, V. (2017). Implementation of lean production practices and manufacturing performance: The role of lean duration. In *Journal of Manufacturing Technology Management* (Vol. 28, Issue 4, pp. 531–550). Emerald Group Publishing Ltd. https://doi.org/10.1108/JMTM-08-2016-0112

William Faulkner, Fazleena Badurdeen. (2014). Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance. *Journal of Cleaner Production*, Volume 85, 15 December 2014, Pages 8-18. https://doi.org/10.1016/j.jclepro.2014.05.042

www.bps.go.id. (2020, November 3). Output Tabel Dinamis Produksi Batu Bara (Ton). From Https://Kaltim.Bps.Go.Id/Site/ResultTab.

Zahraee, S. M., Hashemi, A., Abdi, A. A., Shahpanah, A., & Rohani, J. M. (2014). *Jurnal Teknologi Lean Manufacturing Implementation Through Value Stream Mapping: A Case Study* (Vol. 68, Issue 3). www.jurnalteknologi.utm.my

Zahraee, S. M., Tolooie, A., Abrishami, S. J., Shiwakoti, N., & Stasinopoulos, P. (2020). Lean manufacturing analysis of a Heater industry based on value stream mapping and computer simulation. *Procedia Manufacturing*, *51*, 1379–1386. https://doi.org/10.1016/j.promfg.2020.10.192