

Analysis and Optimization of Warehouse Sustainability using the Sustainable Value Stream Mapping (SUS-VSM) Method at PT XYZ

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Abstract

Warehouse operations are a critical component of the supply chain system as they manage material flow before entering the production process. The Central Warehouse handles high-volume material operations, requiring an efficient and sustainable warehousing system to support Environmental, Social, and Governance (ESG) targets and the Net Zero Emission 2060 initiative. This study aims to analyze and optimize sustainable warehouse processes using the Sustainable Value Stream Mapping (SUS-VSM) method. The research methodology includes current state SUS-VSM mapping, activity classification into Value Added (VA), Necessary Non Value Added (NNVA), and Non Value Added (NVA), waste analysis, root cause identification using the Five-Whys method, and future state SUS-VSM design. The results indicate that the total lead time of the warehouse process is 4,505.31 minutes, with a value-added time of 36.59 minutes and a Process Cycle Efficiency (PCE) of 0.81%. The dominant wastes identified include waiting, transportation, motion, inventory, and overprocessing, mainly caused by the lack of system integration, reliance on physical documents, and manual verification processes. Proposed improvements, including the implementation of Radio Frequency Identification (RFID), a Warehouse Management System (WMS), document digitalization, and material flow optimization, reduce lead time to 4,384.19 minutes and increase PCE to 0.83%, while also improving sustainability indicators such as waste efficiency, energy process, safety, and time efficiency. These findings indicate that the proposed improvements have the potential to enhance warehouse operational efficiency and support a more sustainable warehousing system.

Keywords: Five whys; process activity mapping; RFID; sustainable value stream mapping; warehouse

1. Introduction

In the last decade, the global industrial sector has faced increasingly complex pressures due to the energy crisis, climate change, and geopolitical instability, all of which directly impact rising energy consumption and carbon emissions. The industry's dependence on fossil-based energy remains a major issue, as it significantly contributes to global carbon emissions. The industrial sector accounts for approximately 30% of global carbon emissions and consumes around 37% of the world's primary energy, most of which is still derived from fossil fuels [1]. As global commitment to the Net Zero Emission (NZE) target increases, the transformation toward more efficient and sustainable industrial systems has become inevitable.

In the national context, Indonesia continues to face challenges in energy transition and industrial operational

efficiency. The renewable energy mix, which has only reached approximately 13.1%, indicates a high dependence on conventional energy sources [2]. In addition, high logistics costs and the contribution of industrial sector emissions suggest that supporting systems such as warehousing have not been optimally developed to enhance energy efficiency and sustainability. This highlights that efforts to improve industrial performance are not limited to production processes but also include logistics and warehousing systems as integral components of the supply chain.

In line with this, the concept of sustainable warehousing has emerged as an approach that integrates economic, environmental, and social aspects into warehouse operations [3]. This approach expands the traditional focus, which was previously oriented toward cost and time efficiency, into a more comprehensive perspective that considers environmental and social impacts [4]. The implementation of sustainable warehousing includes several key characteristics, such as

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the level of automation, the adoption of green lean practices, employee training, and efficient use of resources and energy [5]. Its performance is typically evaluated using triple bottom line indicators covering economic, environmental, and social dimensions [6].

In practice, one of the main challenges in warehouse systems is the high level of waste in various forms, such as waiting time, inefficient material movement, excessive inventory, and activities that do not add value [7]. The concept of waste is essential in identifying inefficient activities and classifying them into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA) activities [8]. This waste identification serves as the foundation for improving warehouse operational efficiency [9].

The operational processes at the Central Warehouse reveal several forms of waste that contribute to inefficiencies in warehousing activities. Waste of time occurs due to delays in administrative procedures, material verification, and waiting periods during operational activities. Meanwhile, waste of transportation and waste of motion arise from inefficient material handling processes, unnecessary operator movements, and suboptimal warehouse layout arrangements that require longer travel distances within the warehouse area. In addition, waste of inventory is reflected in the accumulation of materials stored for extended periods without immediate utilization, resulting in excessive storage and increased holding costs. These conditions indicate that several warehousing activities are still dominated by non-value-added processes that reduce operational effectiveness and productivity.

Based on the mapping results, value-added activities account for only a small portion of the total process time, while non-value-added activities still dominate and cause operational inefficiencies. This condition increases lead time, warehouse operational energy consumption, and carbon emissions. The high level of energy consumption and emissions at the Central Warehouse indicates the need for an analytical approach capable of evaluating operational efficiency and environmental impact in an integrated manner.

One of the methods used to identify waste is Value Stream Mapping (VSM), which is capable of mapping material and information flows and identifying non-value-added activities [10]. However, conventional VSM still has limitations as it does not fully integrate sustainability aspects. Therefore, Sustainable Value Stream Mapping (SUS-VSM) was developed to incorporate economic, environmental, and social indicators into process analysis [11]. This approach enables a more comprehensive performance evaluation, including energy consumption, carbon emissions, and social aspects such as occupational safety and employee training [12].

In addition to analytical approaches, technological advancements also play a crucial role in improving warehouse system efficiency. Radio Frequency Identification (RFID) technology, as part of the Automatic Identification (Auto-ID) system, enables real-time identification and tracking of materials without direct

contact [13]. The advantages of RFID in terms of speed, accuracy, and the ability to read multiple tags simultaneously make it an effective solution for improving material flow transparency and reducing human error in logistics systems.

As a state-owned enterprise in the maritime sector, XYZ shipbuilding company has a highly complex supply chain, with warehouse operations serving as the central hub for material distribution to various production lines. However, the current conditions indicate the presence of various wastes in warehouse processes, resulting in high lead times, low process efficiency, and high operational energy consumption and carbon emissions. This suggests that conventional approaches focusing solely on operational efficiency are insufficient to address sustainability challenges.

Previous studies have shown that the integration of Industry 4.0 technologies with lean warehousing can improve operational efficiency; however, they remain limited in incorporating environmental aspects [14]. Meanwhile, the implementation of SUS-VSM has been proven effective in enhancing sustainability performance across various industrial sectors, although its application in heavy industrial warehousing systems is still relatively limited [15]. This indicates a research gap in integrating lean approaches, sustainability, and digital technology within complex industrial warehousing contexts.

Based on this background, this study aims to analyze and optimize sustainable warehouse processes in an XYZ shipbuilding company using the Sustainable Value Stream Mapping (SUS-VSM) method with Radio Frequency Identification (RFID) technology. The study is expected to enhance operational efficiency, reduce waste, and lower energy consumption and carbon emissions, thereby supporting the achievement of Net Zero Emission targets and the implementation of Environmental, Social, and Governance (ESG) principles in the manufacturing sector.

2. Method

The data collection method used in this study was direct observation in the warehouse area. The analytical method applied was Sustainable Value Stream Mapping (SUS-VSM), an extension of Value Stream Mapping (VSM) that evaluates process efficiency while incorporating sustainability aspects based on the triple bottom line: economic, environmental, and social dimensions. In this method, activities were classified into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA). The analysis also included waste identification and its impact on sustainability indicators such as time efficiency, energy consumption, waste generation, employee job satisfaction, and absenteeism rates. The implementation stages of SUS-VSM consisted of initial identification of warehouse activities through direct observation, followed by the development of the current state map based on material, information, and sustainability flows. Waste and sustainability impacts were then identified and analyzed using the Five-Whys method to determine root causes. Based on the analysis results, improvement proposals were developed to reduce waste and enhance sustainability performance. Finally, a

future state map was designed to illustrate improvements in process efficiency, environmental impact reduction, and operator working conditions in accordance with triple bottom line principles.

3. Results and Discussion

3.1. Warehouse process flow

The analyzed process flow covers the entire sequence of activities, starting from material receiving (inbound), storage, and ending with material dispatch (outbound). The visualization of the warehouse process flow is presented in Fig. 1.

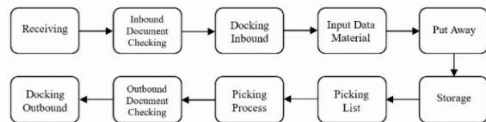


Figure 1. Warehouse process flow activities

The detailed explanation of each stage in the warehouse process flow is as follows:

- **Receiving**
Receiving is the process of accepting incoming materials. Physical and quantity verification is conducted to determine material acceptance.
- **Inbound document checking**
Document checking is conducted to verify delivery and contract documents, ensuring consistency between the documentation and the received materials.
- **Docking inbound**
Docking inbound is the temporary placement of approved materials. Materials are stored before being transferred to storage.
- **Material data input**
Material data input records materials into the inventory system. Identification codes are assigned for traceability.
- **Put away**
Put away transfers materials to designated storage locations. Placement is based on location codes and classification.
- **Storage**
Storage is the stage where materials are stored in designated locations until requested by users. At this stage, materials become part of active warehouse inventory.
- **Picking list**
The picking list is a document containing material requests submitted by users, including specifications and required quantities.
- **Picking process**
The picking process involves retrieving materials from storage based on the picking list and preparing them for inspection prior to dispatch.
- **Outbound document checking**
This stage involves re-verification of materials to be dispatched, including physical condition and quantity, to ensure accuracy before shipment.
- **Docking outbound**
Docking outbound is the temporary placement of materials in a transit area prior to loading onto

vehicles. This stage aims to facilitate the loading process and minimize inefficient material handling movements.

Table 1. Process activity mapping

Activity	Time (Minutes)	O	T	I	S	D	VA/NVA/NNVA
<i>Receiving</i>							
A1	3.35	✓					NNVA
A2	5.03	✓					NNVA
A3	4.19			✓			NNVA
A4	6.71			✓			NNVA
A5	16.77					✓	NVA
<i>Inbound Document Checking</i>							
B1	5.37			✓			NNVA
B2	10.76			✓			NNVA
B3	2.68	✓					NNVA
B4	6.71	✓					VA
<i>Docking Inbound</i>							
C1	25.62	✓					NNVA
C2	12.81		✓				NNVA
C3	12.81	✓					NNVA
C4	12.81					✓	NVA
<i>Input Data</i>							
D1	4.10	✓					VA
D2	5.47	✓					VA
<i>Put Away</i>							
E1	10.51					✓	NVA
E2	17.54		✓				NNVA
E3	7.02	✓					NNVA
<i>Storage</i>							
F1	4,112.64					✓	NNVA
F2	13.60	✓					VA
<i>Picking List</i>							
G1	4.03	✓					NNVA
G2	5.37			✓			NNVA
G3	20.13					✓	NVA
<i>Picking Process</i>							
H1	17.85					✓	NVA
H2	26.77	✓					NNVA
H3	8.92			✓			NNVA
H4	13.38		✓				NNVA
<i>Outbound Document Checking</i>							
I1	8.04			✓			NNVA
I2	5.37			✓			NNVA
I3	6.71	✓					VA
<i>Docking Outbound</i>							
J1	12.81		✓				NNVA
J2	25.63					✓	NVA
J3	25.62	✓					NNVA
J4	12.81	✓					NNVA
J5	8.54	✓					NNVA
J6	6.83			✓			NNVA

3.2. Current state map (current SUS-VSM)

The Current State Sustainable Value Stream Mapping (SUS-VSM), as shown in Figure 2, illustrates the flow of materials and information from receiving to distribution while identifying VA, NNVA, and NVA activities across economic, environmental, and social aspects. The results indicate a total lead time of 4,505.31 minutes and a value-added time of 36.59 minutes, showing the dominance of NNVA and NVA activities. This condition reflects inefficient material flow, high energy usage, low process efficiency, and unbalanced sustainability performance, highlighting the need for improvement.

3.3. Waste identification and sustainability impact

Process Activity Mapping (PAM) is used to map all activities in the warehouse process to identify value-added and non-value-added activities, allowing waste to be identified and process improvements to be implemented. In this study, activities were identified through direct observation and classified into five categories: operation, delay, transportation, inspection, and storage, followed by percentage calculations for each category. The results identified 36 activities, which were subsequently mapped in the PAM, as presented in Table 1.

After mapping the warehouse activities, the frequency and time percentages of each category were calculated to identify dominant operational activities. The results are presented in Table 2.

Warehouse process activities were further classified into Value Added (VA), Necessary Non-Value Added (NNVA), and Non-Value Added (NVA) categories. The frequency and time percentages of each classification are presented in Table 3.

Table 2. Frequency and time percentage of each category

No	Activity	Total	Percentage	Time (Minutes)	Percentage
1	Operation	16	44%	170.87	4%
2	Transportation	4	11%	56.54	1%
3	Inspection	9	25%	61.56	1%
4	Storage	1	3%	4,112.64	91%
5	Delay	6	17%	103.70	2%
Total		36	100%	4,505.31	100%

Table 3. Frequency and time percentage of each classification

No	Classification	Total	Percentage	Time (Minutes)	Percentage
1	VA	5	14%	36.59	1%
2	NNVA	25	69%	4,365.02	97%
3	NVA	6	17%	103.70	2%
Total		36	100%	4,505.31	100%

The economic dimension in this study was analyzed to measure warehouse operational efficiency based on process time utilization and inventory accumulation levels. In the Sustainable Value Stream Mapping (SUS-VSM) approach, the analysis focuses on two main parameters, namely time efficiency and inventory level, as presented in Table 4.

Table 4. Recapitulation of time efficiency and inventory level

Process Stage	CT (Minutes)	VA (Minutes)	Inventory Time (Minutes)	Time Efficiency (%)	Inventory Level (%)
Receiving	36.05	0	16.77	0%	46.5%
Inbound Document Checking	25.52	6.71	0	26.3%	0%
Docking Inbound	64.05	0	12.81	0%	20%
Input Data Material	9.57	9.57	0	100%	0%
Put Away	35.07	0	10.51	0%	30%
Storage	4,126.24	13.6	4,112.64	0.3%	99.7%
Picking List	29.53	0	20.13	0%	68.2%
Picking Process	66.92	0	17.85	0%	26.7%
Outbound	20.12	6.71	0	33.3%	0%
Document Checking	92.24	0	25.63	0%	27.8%
Docking Outbound					

Table 5. Recapitulation of waste efficiency and energy process

Process Stages	Waste Generated (kg/year)	Waste Handled (kg)	Waste Efficiency (%)	Total Time (Minutes)	Energy Process (kWh)	Energy Process (%)
Receiving	3.72	0	0	36.05	244.21	0.80%
Inbound Document Checking	2.48	0	0	25.52	172.88	0.57%
Docking Inbound	-	-	-	64.05	433.89	1.42%
Input Data Material	2.48	0	0	9.57	64.83	0.21%
Put Away	-	-	-	35.07	237.57	0.78%
Storage	-	-	-	4,126.24	27,952.09	91.59%
Picking List	2.48	0	0	29.53	200.04	0.66%
Picking Process	-	-	-	66.92	453.33	1.49%
Outbound Document Checking	1.24	0	0	20.12	136.30	0.45%
Docking Outbound	-	-	-	92.24	624.85	2.05%

The analysis of environmental indicators under existing conditions was conducted to evaluate the impact of warehouse operations on resource utilization and waste generation. In this study, the environmental indicators consist of two main parameters, namely waste efficiency (administrative paper waste) and energy process (energy consumption at each workstation), as presented in Table 5.

In the Sustainable Value Stream Mapping (SUS-VSM) approach, social indicators are used to assess workforce stability and occupational safety levels at each stage of the inbound, storage, and outbound processes, as presented in Table 6.

Table 6. Recapitulation of employee retention and safety levels

Month (2025)	No. of Employees	No. of Retained Employees	Satisfaction (%)	Number of Work Accidents	Safety (%)
January	8	8	100%	0	100%
February	8	8	100%	0	100%
March	8	8	100%	0	100%
April	8	8	100%	0	100%
May	8	8	100%	0	100%
June	8	8	100%	0	100%
July	8	8	100%	0	100%
August	8	8	100%	0	100%
September	8	8	100%	0	100%
October	8	8	100%	0	100%
November	8	8	100%	0	100%
December	8	8	100%	0	100%

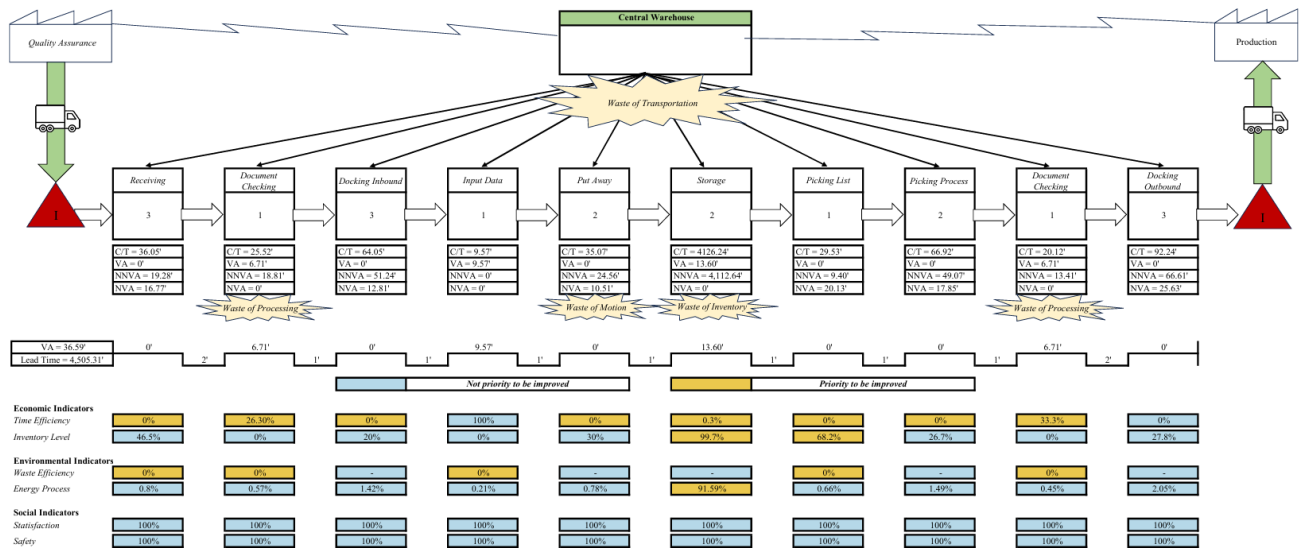


Figure 2. Current state sustainability value stream mapping

Table 7. Waste cause analysis using the five-whys method

Code	Activity	Why 1	Why 2	Why 3	Why 4
J2	Waiting for production vehicles (NVA)	Production vehicles wait before materials are delivered	Materials are not ready when the vehicles arrive	The picking and checking processes require a long time	The scheduling coordination between warehouse and production is not synchronized
G3	Delay in approval from supervisors (NVA)	The approval process takes a long time	Supervisors are not always available on site	Approval still uses physical documents	The approval flow is carried out manually
H1	Searching for material locations (NVA)	Operators require a long time to find materials	Material locations are not precisely identified	Material location recording is still manual	The material identification and tracking system is not integrated
A5	Waiting for unloading queue at the dock area (NVA)	Materials wait before the unloading process	The dock area is used alternately	Docking capacity is limited compared to the number of arriving materials	The scheduling of material arrivals is not yet optimal
C4	Waiting for data input process before put away (NVA)	Materials wait before being moved to the storage area	The data input process has not been completed	Data input is carried out manually	Operators must record and verify data one by one
E1	Searching for storage locations (NVA)	Operators require a long time to determine storage locations	Storage locations are not clearly identified	Material placement has not implemented a zoning system	The warehouse layout has not been arranged based on material flow
F1	Storage of materials in indoor racks or yard areas (NNVA)	Materials are stored for a long period	Materials have not yet been used in the production process	Material requests from production are not carried out continuously	Incoming material flow and production demand are not balanced

3.4. Waste cause analysis

Overall, the identification results indicate that the dominant wastes in the warehouse system are waiting, transportation, inventory, motion, and overprocessing, which significantly contribute to operational delays. Although some wastes cannot be fully eliminated because they belong to necessary non-value-added (NNVA) activities, they can still be minimized through process improvements. Therefore, a Five-Whys analysis was conducted to identify the root causes of these wastes in warehouse operations, as presented in Table 7.

3.5. Improvement proposal stage

Improvement proposals were developed to reduce waste in the material warehousing process based on root cause identification using the Five-Whys method. The proposed improvements focus on enhancing operational coordination, optimizing material flow, and strengthening warehouse information systems to achieve more efficient and sustainable warehouse processes, as presented in Tables 8 and 9.

Based on Tables 8 and 9, the proposed improvements focus on enhancing material flow efficiency, reducing waiting time, and strengthening the warehouse information system through the implementation of RFID technology integrated with barcodes for automatic and real-time material identification. The integration of these technologies enables faster and more accurate data capture, thereby reducing manual recording activities and minimizing the risk of human error during warehouse operations. In addition, the proposed smart warehouse system is expected to improve material traceability, accelerate operational processes, and support better inventory visibility and warehouse decision-making. Furthermore, the system interface was designed to support inbound, storage, and outbound processes in an integrated and user-friendly manner. The interface provides real-time information access and efficient data management to facilitate warehouse operators in carrying out operational activities more effectively. The proposed user interface design is shown in Figure 3.

Table 8. Improvement proposals

Code	Proposed Improvement
J2	Develop a coordinated material delivery schedule between the warehouse and production departments so that vehicles arrive when materials are ready. Integrate the warehouse information system with the production schedule to improve synchronization of material deliveries.
G3	Implement a digital-based approval system so that the approval process can be carried out without waiting for supervisors to be physically present on site. Integrate the approval workflow with the warehouse information system to accelerate operational administrative processes.
H1	Implement a barcode- or RFID-based material identification and tracking system to facilitate material location searching. Integrate material location records into the Warehouse Management System (WMS) so that material positions can be monitored in real time.
A5	Develop a structured material arrival schedule to reduce unloading queues in the dock area. Optimize the utilization of docking areas and unloading priority arrangements to improve the material receiving process.
C4	Automate the material data input process using an integrated system so that recording activities can be

E1	performed more quickly. Reduce manual verification processes through integration of material data with the warehouse system. Develop a slotting and zoning system for material storage based on material type and movement frequency.
F1	Optimize the warehouse layout according to material flow to facilitate the material placement process. Control inventory levels through material requirement planning that is more integrated with the production process. Implement a Warehouse Management System (WMS) to monitor material movement and storage duration in real time.

Table 9. Sustainable improvement proposals

Sustainability Indicator	Proposed Improvement
Waste Efficiency	The implementation of WMS and barcode/RFID technology reduces physical documents and manual recording, improving waste efficiency from 0% to 50%.
Energy Process	Warehouse layout and material flow optimization reduce material movement and handling time, decreasing energy consumption to 13,866 kWh.
Time Efficiency	RFID, WMS, and material flow optimization reduce non-value-added activities and improve time efficiency from 26% to 32%.

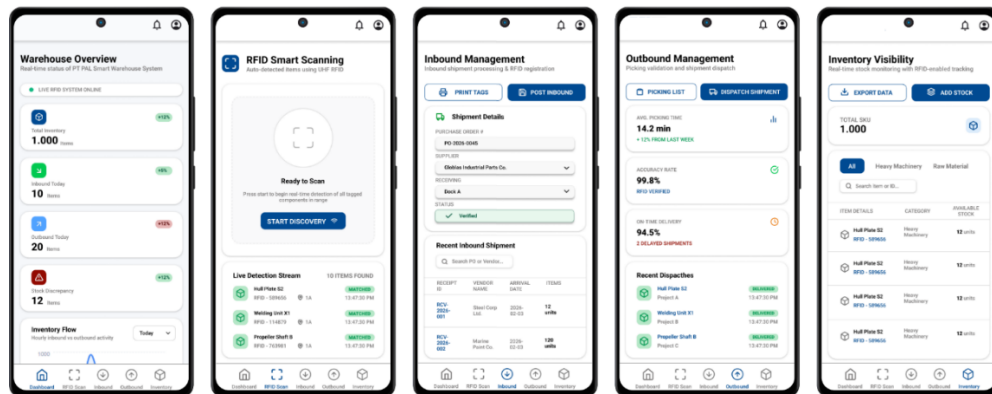


Figure 3. Warehouse system user interface

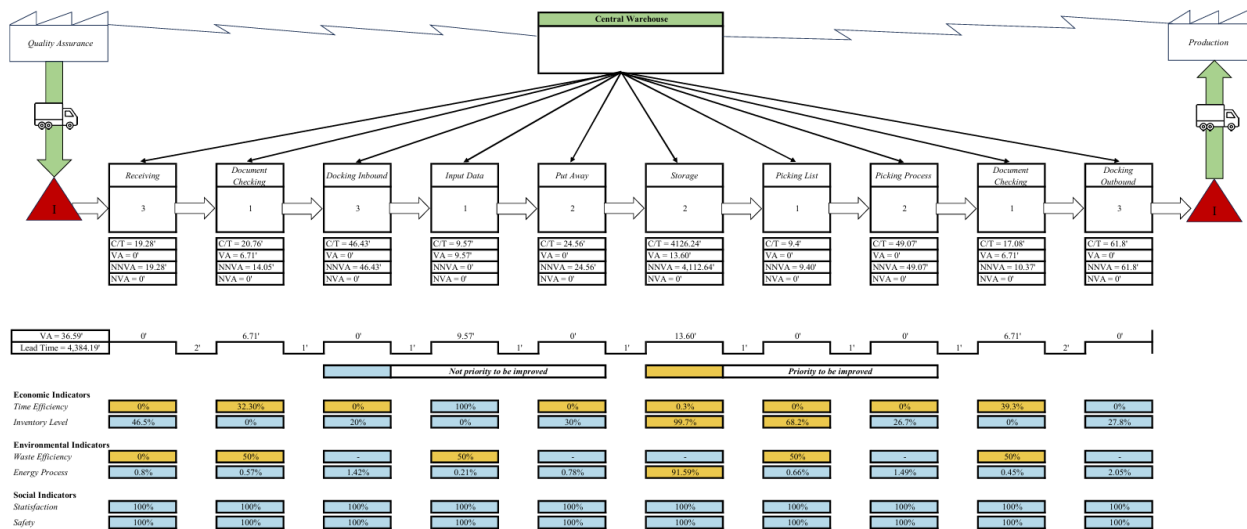


Figure 4. Future state sustainability value stream mapping

3.6. Future state map (future SUS-VSM)

The Future State Sustainable Value Stream Mapping (SUS-VSM), as shown in Figure 4, illustrates warehouse improvements through RFID implementation, system digitalization, and material flow optimization to reduce non-value-added activities and enhance operational efficiency and sustainability. The future state shows a value-added time of 36.59 minutes and a reduced lead time of 4,384.19 minutes. In addition, RFID and the Warehouse Management System improve time efficiency, waste efficiency, and information integration between warehouse and production processes. The future state also serves as a comparison basis for evaluating improvements in Process Cycle Efficiency (PCE), lead time, and sustainability performance.

4. Conclusion

This study concludes that the implementation of Sustainable Value Stream Mapping (SUS-VSM) effectively analyzes and improves sustainable warehouse processes. The current state analysis shows that warehouse operations are still dominated by necessary non-value-added activities, with a total lead time of 4,505.31 minutes, a value-added time of 36.59 minutes, and a Process Cycle Efficiency (PCE) of 0.81%. Dominant wastes identified include waiting, transportation, motion, inventory, and overprocessing, mainly caused by the lack of an integrated warehouse system and manual verification processes. Proposed improvements, including the implementation of Radio Frequency Identification (RFID), development of a Warehouse Management System (WMS), document digitalization, and material flow optimization, reduce the lead time to 4,384.19 minutes and increase the PCE to 0.83%. In addition, improvements were achieved in sustainability indicators such as waste efficiency, energy process, and time efficiency. Overall, the proposed improvements indicate the potential to enhance warehouse operational efficiency and support a more sustainable warehousing system.

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References

- [1] International Energy Agency, "World Energy Outlook 2023," 2023.
- [2] Institute for Essential Services Reform, "Indonesia Energy Transition Outlook (IETO) 2024," Jakarta, 2024.
- [3] V. Popović, M. Kilibarda, M. Andrejić, B. Jereb, and D. Dragan, "A New Sustainable Warehouse Management Approach for Workforce and Activities Scheduling," *Sustainability*, vol. 13, no. 4, 2021, doi: 10.3390/su13042021.
- [4] A. Mohammed, M. M. M. Rahman, G. Demir, B. Shah, and A. Alaya, "When Warehouses Dream: A Systems-Informed Exploration of Industry 5.0 Principles in Warehousing Performance Management," *Int. J. Syst. Sci. Oper. Logist.*, vol. 12, no. 1, 2025, doi: 10.1080/23302674.2025.2559257.
- [5] W. K. Al-Saad, M. Al-Talib, J. A. Garza-Reyes, and S. P. Nadeem, "Sustainable Warehouse Features: A Systematic Literature Review," in *Proceedings of the 13th International Conference on Industrial Engineering and Operations Management*, Manama, Bahrain: IEOM Society International, 2023, pp. 2087–2098.
- [6] E. Zaye and O. O. Ogunyomi-Oluyomi, "Assessment of Supply Chain Sustainability Strategy on Sustainable Performance Indicators: Evidence from Siemens DEGREE Framework (2019–2023)," *Int. J. Supply Chain Logist.*, vol. 9, no. 3, pp. 1–15, 2025.
- [7] U. F. Untsa and B. D. Bernadhi, "Analisis Lean Manufacturing Menggunakan Waste Assessment Model (WAM) dan Value Stream Analysis Tools (VALSAT) untuk Meminimalisasi Waste pada Proses Produksi (Studi Kasus Printex Semarang)," *JUSTI (Jurnal Sist. dan Tek. Ind.)*, vol. 5, no. 4, pp. 479–493, 2024.
- [8] B. P. Bestari and E. Fatma, "Penerapan Lean Warehousing untuk Meningkatkan Kinerja Aktivitas Gudang pada Perusahaan Percetakan Buku," in *Prosiding Seminar Nasional Manajemen Industri dan Rantai Pa*, Surabaya: Program Studi Magister Manajemen Industri, Institut Teknologi Sepuluh Nopember (ITS), 2020, pp. 160–169.
- [9] T. R. Diina, Sriwidodo, E. S. Nurrajjid, and I. Kustiawan, "Penerapan Lean Warehousing pada Gudang Bahan Baku Industri Farmasi PT XYZ," *Maj. Farmasetika*, vol. 9, no. 4, pp. 367–387, 2024, doi: 10.24198/mfarmasetika.v9i4.54864.
- [10] M. N. Rasshif, P. A. Wicaksono, and S. Hartini, "Desain Sustainable Value Stream Mapping untuk Evaluasi Kinerja Keberlanjutan Perusahaan Obat," *Ind. Eng. Online J.*, vol. 12, no. 4, pp. 1–9, 2023.
- [11] M. C. Firdaus, "Desain Sustainable Value Stream Mapping untuk Meningkatkan Kinerja Keberlanjutan Perusahaan CPO (Studi Kasus: PKS Bunut PT Perkebunan Nusantara VI)," *Ind. Eng. Online J.*, vol. 11, no. 3, 2022.
- [12] S. Hartini, J. Manurung, and Rumita, "Sustainable-Value Stream Mapping to Improve Manufacturing Sustainability Performance: Case Study in a Natural Dye Batik SME's," in *IOP Conference Series: Materials Science and Engineering*, IOP Publishing, 2021, p. 012066. doi: 10.1088/1757-899X/1072/1/012066.
- [13] I. Afif, Pratikto, and Y. Sumantri, "Tinjauan Literatur Teknologi Identifikasi RFID dan QR-Code sebagai Alat Pendukung Aliran Informasi di Dunia Industri," *Talent. Conf. Ser. Energy Eng.*, vol. 6, no. 1, pp. 505–512, 2023, doi: 10.32734/ee.v6i1.1854.
- [14] J. S. Sihombing, Y. Sibarani, and M. Al Faridzi, "Transformasi Warehouse di Perusahaan Industri dengan Sistem Teknologi 4.0," *J. Logist.*, vol. 4, no. 1, pp. 36–44, 2025, doi: 10.62375/logistics.v4i1.673.
- [15] Nurwidiana and N. Ela, "Designing Sustainable Value Stream Mapping to Enhance Sustainability Performance in the Tofu Industry," in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing, 2025, p. 012026. doi: 10.1088/1755-1315/1543/1/012026.