The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2023

Volume 23, Pages 452-463

ICRETS 2023: International Conference on Research in Engineering, Technology, and Science

Integrated Model of Lean and Risk Mitigation for Sustainability Performance Measurement in the Lubricants Manufacturing Industry

Fara Kamila Hudy
Institute Technology of Sepuluh Nopember

Nidaru Ainul Fikri
Institute Technology of Sepuluh Nopember

Udisubakti Ciptomulyono
Institute Technology of Sepuluh Nopember

Abstract: Green companies are needed for manufacturing related to maintaining the business. Evaluating sustainability performance in manufacturing processes and proposing strategies for sustainable growth is important. This study measures the performance of manufacturing sustainability in the lubricating oil industry sector. Several previous studies on measuring sustainable manufacturing performance only considered lean and green aspects. This study fills the existing gap by adding a risk perspective in measurement. Several suggestions for improvement analyzed from measurements of sustainability performance and risk mitigation, are validated using the BORDA. The lean and green philosophy is applied with the Sustainable Value Stream Mapping approach. Meanwhile, risk mitigation is analyzed using the House of Risk approach. The results of the assessment of sustainability performance measurements are analyzed using the efficiency approach and BORDA for weighting. This research is expected to be able to provide suggestions for improvements for manufacturing that are efficient and feasible to implement. So that high sustainability performance can be achieved with low risk.

Keywords: Sustainable value stream mapping, House of risk, BORDA, Manufacturing sustainability perfomance

Introduction

Green company is currently a business requirement because it is related to business continuity. It involves managing environmental factors to prevent pollution and damage to the environment during production, product or service usage by customers, and disposal. These demands and challenges have led to the emergence of the concept of sustainable development in manufacturing, aiming to improve people's quality of life through an environmentally friendly approach (Bogue, 2014). Therefore, it is important to evaluate sustainability performance in a manufacturing company's production process and propose strategies for sustainable growth (Swarnakar et al., 2021).

Lean manufacturing can be defined as the elimination of waste in production systems, including human effort, time, and inventory at each stage of production (Rahman et al., 2013). Lean and green can be implemented together and synergize with each other (Hartini et al., 2020). Companies that simultaneously apply lean and green practices have been proven to have better performance compared to those implementing only one of them (Bergmiller & McCright, 2009; Wiengarten et al., 2013). The application of lean manufacturing supports the achievement of green practices and vice versa. Sustainable manufacturing is a process that minimizes adverse environmental impacts, ensures worker safety, and has a positive long-term impact on the economy during the production process (Mubin et al., 2022). Sustainable manufacturing not only focuses on environmentally friendly production systems but also involves social responsibility with a wider scope, considering lean practices as part of sustainable manufacturing (Joung et al., 2013).

Several studies have been conducted to measure sustainability in manufacturing. Lee et al. (2014) developed concepts and methods to assess manufacturing sustainability performance at the factory level using a single index. Huang & Badurdeen (2018) introduced a framework for measuring sustainability performance at the production level. However, most manufacturing industries lack detailed sustainability data that aligns with the proposed models. Therefore, each manufacturer requires a specific methodology to help measure indicators and improve environmental, economic, and social aspects at the factory level (Hartini et al., 2020).

Operationally, sustainability performance cannot be simply calculated as a percentage. Mapping is also necessary to facilitate production operators' visual understanding of sustainability performance. Furthermore, mapping the production line at each workstation assists decision-makers in making sustainable decisions. Thus, the industry requires a comprehensive methodology to map and measure manufacturing sustainability performance at the production level (Mubin et al., 2022).

According to Hartini et al. (2021), value stream mapping, which evaluates sustainability indicators, was initially introduced by Simon & Mason (2003). Sustainable value stream mapping incorporates the triple bottom line concept into the production line, as first introduced by Brown et al. (2014). Sustainable value stream mapping (SVSM) is a visual representation of the energy flow and waste generated in the manufacturing process (Ikatrinasari et al., 2018). Previous studies have utilized SVSM to measure and map manufacturing sustainability performance, such as Hartini et al. (2020), who proposed an MSA assessment framework based on SVSM and Delphi-AHP for the furniture industry. Similarly, Mubin et al. (2022) suggested using SVSM and weighting it with AHP, while also incorporating indicators of mental and physical workload in the plastics industry.

However, there are still limitations in mapping and measuring sustainability performance using SVSM. These measurements have not considered failure or risk factors and the interdependencies between production processes. Every production process entails risk, yet these risk factors are often overlooked or evaluated independently (Shah et al., 2012). Failure to effectively mitigate risks can leave companies behind in the ever-changing business landscape, as a company's future depends on its ability and responsiveness to external environmental changes (Soosay et al., 2016).

Inadequate management of risks can negatively impact company performance, whereas active and systematic control of risk variables can support business success (Oduoza, 2020). Therefore, risk factors should be incorporated into the evaluation of the MSA score and recommendations for improvement. Additionally, no research has been conducted on measuring the MSA score in the lubricating oil manufacturing industry. To reduce risk, the House of Risk (HOR) approach can be used. BORDA is used to weigh each variable in order to identify the cause factor order. As a result, the proposed improvements are considered worthy of implementation as they take into account all aspects, including waste, sustainability, and potential future risks.

Lubricants are substances utilized to minimize friction and wear between interacting surfaces, enabling relative motion in solids. Aside from their primary role in reducing wear and friction, lubricating fluids serve various other functions. They act as coolants in metalworking, prevent corrosion, facilitate power transfer, act as liquid seals in suspensions and moving contacts, and remove worn particles. Practical lubricating oils need to remain in liquid form across a wide temperature range. They must possess a low pour point to ensure pumpability during equipment startup at very low temperatures. Simultaneously, they should have a high flash point for safe operation and exhibit minimal volatility at maximum operating temperature.

The viscosity of lubricating oil needs to be adjusted based on the engine's compression. If the viscosity is too high for a given load and speed, it can lead to wasted engine power as it processes a thick layer of lubricant. Lubricating oil plays a crucial role in maintaining the machinery and equipment's operational continuity, despite its relatively small usage volume. Its application extends beyond the automotive industry and is also essential in various industrial and mining settings, ensuring the proper functioning of engine systems.

The measuring MSA scores using SVSM while considering sustainable risks in the lubricant manufacturing industry is required. The selected indicators are displayed using SVSM, waste analysis is done, and the efficiency of each indicator is measured. In addition, sustainable risks in the economic, social, and environmental aspects of each process are identified using the House of Risk approach (HOR).

Considerations are assigned to indicators in SVSM and sustainable risk to determine the level of importance of each. Furthermore, the results of mapping and indicator assessment, through SVSM and identification of sustainable risk using HOR, are used to measure manufacturing sustainability scores. The research also uses the Borda Method for any proposed improvements based on SVSM indicators and sustainability risks. This research has made a significant contribution to this field by filling a gap in research into the lubricant industry. It provides a new reference for operations managers to assess sustainability performance in the company, considering its sustainability risk factors in various aspects. The study helps identify waste and risk areas, revealing the level of sustainability that the company achieves. In addition, the proposed improvements are efficient, feasible, and do not pose implementation risks.

Lean, Green and Sustainable Manufacturing

There are two main meanings associated with the term lean in the manufacturing context. First, lean refers to the goal of minimizing waste and maximizing value in the production process (Nawanir et al., 2018). This concept was first introduced by Toyota in the 1950s and since then has been widely adopted in manufacturing industries around the world. The goal of Lean Manufacturing (LM) is to eliminate activities that do not add value to the final product, including overproduction, excess inventory, defects, waiting time, unnecessary movements, and excessive processing. By eliminating waste and increasing efficiency, LM can reduce costs, improve quality, and enhance customer satisfaction.

The term lean is also used broadly to refer to a philosophy of continuous improvement and waste reduction in all aspects of business operations, not just in the manufacturing context. This wider application of lean principles is sometimes referred to as lean management (Leong et al., 2019). The LM approach focuses on increasing the productivity of the production process through adding value and reducing the 7 wastes or seven wastes in operations, namely over production, waiting, inventory, motion, transportation, over processing, defects.

Green manufacturing is focused on reducing the environmental impact of the manufacturing process while maximizing efficiency and value for customers (Abdul-Rashid et al., 2017). This theory is based on the integration of environmental sustainability into the LM principle, which emphasizes identifying and reducing waste, optimizing energy and resource consumption, and continuously improving production processes (Leong et al., 2019). The theory of sustainability focuses on assessing and improving the sustainability performance of manufacturing processes. Sustainability emphasizes the importance of considering social, economic, and environmental factors when evaluating the sustainability of manufacturing processes.

The main goals of sustainability are to reduce environmental impact, increase social and economic outcomes, and promote long-term sustainability. By considering these factors, organizations can improve their sustainability performance and contribute to a more sustainable future (Swarnakar et al., 2021). Overall, the manufacturing process has a large impact on the environment due to high energy consumption and unwanted waste disposal (Duflou et al., 2012). Manufacturing processes must be designed and operated in such a way as to reduce waste, eliminate hazardous substances, save material and energy, and minimize physical hazards (Jovane & Westkämper, 2008).

Many initiatives have been developed to reduce the impact of manufacturing on the environment, such as reducing energy consumption and CO_2 emissions, minimizing waste, and making material use more efficient. Effective energy management can significantly reduce manufacturing operating costs and increase production flexibility and quality (Christoffersen et al., 2006; Despeisse et al., 2012; Fang et al., 2011; Jayal et al., 2010; Pajunen et al., 2012).

Measurement of Manufacturing Sustainability Performance in SVSM

The efficiency measurement of each indicator described in Table 1 is visualized in the Sustainable-VSM map. In Hartini et al. (2020) the value of the efficiency of the performance indicators obtained. If a value below 65 is critical it will be represented by red between 60 and 90 is moderate and represented by yellow, more than 90 is very good and represented by green.

Table 1. Efficiency formula for sustainability indicators

No.	Indicator	Input	Formula	References
1	Time (minute)	TE = time efficiency VAT = time in value-added activities TT = total time NVAT = time in non-value-added activities *n* = process to *n*	$TE = \frac{VAT}{TT}$ $VAT = \sum_{i=1}^{n}(VAT_i)$ $NVAT = \sum_{i=1}^{n}(NVAT_i)$ $TT = VAT + NVAT$	Hartini et al. (2020)
2	Quality	QE = quality efficiency ND = number of defects TM = total material	$QE = 1 - (ND/TM)$	Hartini et al. (2020)
3	Material (kg)	ME = material efficiency MC = number of material consumed PR = number of product released	$MC = \sum MC_n$ $PR = \sum PR_n$ $ME = MC/PR$	Hartini et al. (2020); Helleno et al. (2017); Vinodh et al. (2014)
4	Energy (kWh)	EE = energy efficiency EP = Amount of energy used for production ED = amount of energy used for domestic TE = Total energy	$EP = \sum EP_n$ $ED = \sum ED_n$ $TE = EP + ED$ $EE = EP/TE$	Hartini et al. (2020); Helleno et al. (2017); Vinodh et al. (2014)
5	Water Consumption	WE = Water efficiency WP = amount of water used for production WD = amount of water used for domestic TW = total water	$WP = \sum WP_n$ $WD = \sum WD_n$ $TW = WP + WD$ $WE = AW/TW$	Faulkner and Badurdeen (2014)
6	Satisfaction level	SE = Satisfaction Efficiency TO = number of employee turnover NE = number of employees	$SE = 1 - (TO/NE)$	Hollmann et al. (Hollmann et al. 1998); Mubin et al. (Mubin et al. 2022)
7	Health Level	HE = Health Efficiency NA = number of employees absent NE = number of employees	$HE = 1 - (NA/NE)$	Hart and Staveland (1988); Mubin et al. (Mubin et al. 2022)
8	Employee training level	E_HRD = Human Resources & Development Efficiency NT = Number of employee training NE = Number of empolyee	$E_{HRD} = NT/NE$	Hartini et al. (2020)

House of Risk (HOR)

House of Risk is a new method of analyzing risk. Its application uses the principles of FMEA (Failure Mode and Error Analysis) to measure risk quantitatively combined with the House of Quality (HOQ) model to prioritize risk agents that must be prioritized first and then choose the most effective actions to reduce potential risks posed by agents. risk. The HOR model underlies risk management on a prevention focus, namely reducing the possibility of risk agents occurring. So the earliest stage is to identify risk events and risk agents. Usually one agent can cause more than one risk event. Adapting from the FMEA method, the risk assessment that is applied is the Risk Priority Number (RPN) which consists of 3 factors, namely the probability of occurrence, the severity of the impact that appears, and detection. The HOR method only assigns probabilities to risk agents and the severity of risk events. Because there is a possibility that one risk agent causes more than one risk event, it is necessary to have an aggregate potential risk quantity of the risk agent. Adapting the House of Quality (HOQ) model to define risk agents should be given priority as a precautionary measure. A rating is given to each risk agent based on the magnitude of the ARPj value for each j risk agent. Therefore, if there are many risk agents, the company can first select the agent with the greatest potential to cause risk events. The model with these two distributions is called the House of Risk (HOR) which is a modification of the HOQ model (Pujawan & Geraldin, 2009).

Borda

Borda is a method of voting used in a group decision support system for selecting a single winner or multiple winners, where voters give a rating to the selected alternative. The Borda method determines the winner by giving a certain number of points to each alternative according to the rating given by each voter. The winner is determined by the final number of points each alternative collects from each voter, with the voter with the highest number of points selected to be the winner. (Sidiq& Wardhana, 2018).

The Borda method operates on the principle of ranking and rating various choices. It assigns higher scores to options with higher rankings, gradually reducing the scores for lower-ranked options until they reach a minimum of 0 or 1. In essence, the Borda method mandates voters to both rank and assign a numerical value to each candidate. For example, the top-ranked choice receives a score of 3, the second-ranked choice gets a score of 2, and so on for each ranking. The third is given a value of 0. A board is a method of voting used in the decision-making of a group for the selection of a single winner or multiple winners. The board determines the winner by assigning a certain number of values to each alternative. Then the winner will be determined by the number of values collected alternately. In a group decision-support system, one of the problems we often face is how to aggregate the opinions of decision-makers to produce the right decision (Syaputra, 2020).

Method

The lean concept is intended to reduce costs and improve product quality by eliminating waste, while sustainable manufacturing focuses on efforts to protect the environment and achieve sustainability. In research, value stream mapping (VSM) is used as an approach to measuring company performance. VSM can identify inefficient activities and measure their efficiency level quantitatively. In addition, this research also utilizes the advantages of green and sustainable manufacturing to consider efforts to save the environment and achieve sustainability, things that have not been considered in previous lean manufacturing approaches. The integration of lean, green and sustainable manufacturing will be used as a basis for developing a comprehensive sustainability performance measurement model for manufacturing companies.

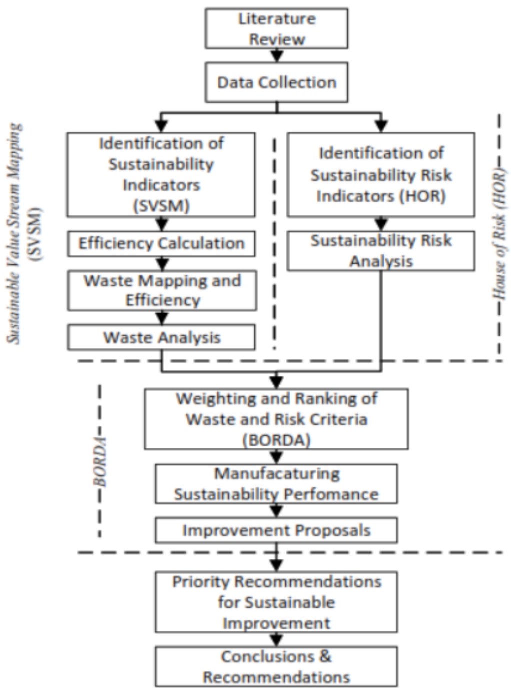

Figure 1. Research framework

The measurement model development process begins with selecting relevant indicators for the manufacturing company concerned. These indicators come from the concepts of lean and sustainable manufacturing so that they include economic, environmental, and social dimensions. Furthermore, a value stream mapping (VSM) is developed which is integrated with the selected indicators. VSM initially only paid attention to economic indicators, then developed into a sustainable-VSM involving environmental and social indicators. Indicators in sustainable-VSM are measured using an efficient approach. The resulting indicator score then becomes the basis for measuring the sustainability performance of manufacturing companies in the form of a manufacturing sustainability index.

In addition to utilizing SVSM, this study also uses sustainability risk to complete the perspective in research. Sustainability risk is considered important because it can affect future manufacturing performance. Risk mitigation in this study was carried out using the house of risk (HOR). HOR was developed by Pujawan & Geraldin (2009) by integrating the House of Quality (HOQ) with FMEA. HOR is a method for identifying and calculating risks that arise in the production process to find the right priority for corrective actions to be implemented based on the company's capabilities (Suryanti et al., 2020).

The proposed improvements are then analyzed using the Benefit, Cost, Opportunities, and Risk (BCOR) criteria. Improvement proposals are assessed from various aspects, starting from the advantages that are translated as benefits, unwanted proposals as costs, events that may occur and can be detrimental or profitable as criteria for opportunities, and risks as criteria for risk (Fitria Sari et al., 2020). It is hoped that the proposed improvements will be feasible to implement because they have considered all aspects, both in terms of waste, sustainability and possible risks that may arise in the future. The research framework is arranged schematically to make it easier to understand the direction of the research Figure 2.

Results and Discussion

Operational Aspect of Sustainability Indicator Efficiency

Time Indicators

The process of receiving base oil and additives is carried out by ship. The times calculated in the efficiency calculation are the dipping time and the pumping time. At the time of measurement, the time required for base oil pumping was 2 hours, 24 minutes. With a flow rate of 196.3 Kl/hour. Activities carried out in production consist of receiving and unloading materials, moving materials from the unloading shelter to the warehouse, activities in the warehouse, blending, filling littos, and transferring finished goods to the finished goods warehouse. Some activities are included in value-added activities, and others are included in non-value-added activities. The calculation of time efficiency, the amount of Value Added time, and Non-Value Added Time during the lithos production process is described in Table 2.

Table 2. Calculation of lubricant lead time efficiency

	Formula	Result
VAT Lithos	∑ Value Added Time	91,128 minutes
NVAT Lithos	∑ Non-Value Added Time	24,96 minutes
Total Time lithos	∑VAT + ∑NVAT	116,088 minutes
Time Efficiency (TE)	(∑VAT) / TT	0,78499
Percent efficiency	(TE) x 100 %	78,499 %

During the production process of Lihtos packaged lubricants, the amount of time needed for value-added activities (value-added time) is 91.128 minutes. While the time required for activities that are not value-added (Non-value-added activities) is 24.96 minutes, The total time required in the lithos packaging lubricant production process is 116.088 minutes. The time efficiency (TE) of the Lihtos packaged lubricant production process is 78.499%.

Quality Indicators

From the data collection process, the efficiency calculation results are as follows: The calculation of quality efficiency is based on a comparison between the amount of material that has defects and the total material. The number of product defects, total material, and quality efficiency calculations are described in Table 3.

Table 3. Calculation of quality efficiency

	Formula	Result
Number of Defect (ND)	∑ Number of Defect	212591 pcs
Total Material ™	∑ TM	36434357 pcs
Quality Efficiency (QE)	1-(∑ ND / TM)	0,9942
Percent efficiency	(TE) x 100 %	99,42 %

During the lubricant production process, the number of materials that experience defects during the period June 2022 to.d. May 2023 of 212591 pcs. While the total material received during the period June 2022 to. May 2023 of 36434357 minutes. The quality efficiency (QE) of the Lihtos packaged lubricant production process is 99.42%.

Material Indicators

From the data collection process, the material efficiency calculation results are obtained as follows: The calculation of material efficiency is based on a comparison between the amount of hydrocarbon material consumed and the actual amount of lubricant production. Total hydrocarbon material consumed, total lubricant production realization, and material efficiency calculations are described in Table 4.

Table 4. Calculation of quality efficiency

	Formula	Result
Number of Material Consumed (MC)	∑ Number of Material Consumed	114.110.299 liters
Number of Product Realesed (PR)	∑ Number of Product Realesed	112.858.482 liter
Material Efficiency (ME)	PR / MC	0,9890
Percent efficiency	(ME) x 100 %	98,90 %

During the lubricant production process, the amount of material consumed during the period June 2022 to May 2023 was 114,110,299 liters. Meanwhile, the number of products released in the same period was 112,858,482 liters. The material efficiency (ME) of the lubricant production process is 98.90%.

Efficiency of Environmental Aspect Sustainability Indicators

Energy Consumption

From the data collection process, the energy consumption efficiency calculation results are obtained as follows: The calculation of energy consumption is based on a comparison between the amount of energy consumed for production and total energy. Total electrical energy consumed, total energy, and energy consumption calculations are described in Table 5.

Table 5. Calculation of energy consumption efficiency

	Formula	Result
Amount of Energy used for Production each month (EP)	∑ Amount of Energy Used for Production each month	1.412.018,27 kWh
Amount of Energy used for domestic each month (ED)	∑ Amount of Energy used for domestic each month	546.778,68 kWh
Total Energy (TE)	∑ EP + ∑ ED	1.958.796,95 kWh
Energy Efficiency (EE)	EP / TE	0,72086
Percent Efficiency	(EE) x 100 %	72,086%

During the lubricant production process, the amount of energy consumed for production during the period June 2022 to.d. May 2023 of 1,412,018.27 kWh. Meanwhile, the amount of energy used domestically is 546,778.68 kWh. The total energy consumed is 1,958,796.95 kWh. The energy efficiency (EE) of the lubricant production process is 72.086%.

Water Consumption

From the data collection process, the water consumption efficiency calculation results are obtained as follows: The calculation of water consumption is based on the ratio between the amount of water used for production and the total water use. Total water used for production, total domestic water use, total water use, and calculated water consumption are presented in Table 6. During the lubricant production process, the amount of water consumed for production during the period June 2022 to May 2023 was 11607.155 m3. While the amount of water used for domestic use is 5169.164 m3. The total amount of water consumed is 16776.32 m3. The water efficiency (WE) of the lubricant production process is 69.187%.

Table 6. Calculation of water consumption

	Formula	Result
Amount of Water used for Production each month (WP)	∑ Amount of Water Used for Production each month	11607,155 m^3
Amount of Water used for domestic each month (WD)	∑ Amount of Water used for domestic each month	5169,164 m^3
Total Water (TW)	∑ WP + ∑ WD	16776,32 m^3
Water Efficiency (WE)	WP / TW	0,69187
Percent efficiency	(WE) x 100 %	69,187%

The Efficiency of Social Aspect Sustainability Indicators

Satisfaction Level

From the data collection process, the efficiency calculation results are as follows: The calculation of the satisfaction level is based on a comparison between the number of employee turnovers, or the number of employees who resign, and the total number of employees. The number of employees who resigned, the total number of employees, and the calculation of the satisfaction level are described in Table 7. The number of workers who resigned during the period June 2022 to May 2023 is 10 people. The total number of workers involved in the company is 300. Satisfaction Level (SL) from lubricant manufacturing is 96.667%.

Table 7. Calculation of satisfaction level

	Formula	Result
Number of Employee Turnover (TO)	∑ Number of Employee Turnover (TO)	10 people
Number of Employee (NE)	∑ NE	300 people
Satisfaction Level (SL)	1-(∑ TO / NE)	0,96667
Percent efficiency	(SL) x 100 %	96,667 %

Health Level

From the data collection process, the efficiency calculation results are as follows: The calculation of health level is based on a comparison between the number of employee absentees or the number of workers who are sick and the total number of employees during the period June 2022 to May 2023. The number of sick workers, total workers, and health level calculations are described in Table 8. The number of workers who received sick leave during the period June 2022–May 2023 was 23. The total number of workers involved in the company is 300. The health level (HL) in lubricant manufacturing is 92.33%.

Table 8. Calculation health level

	Formula	Result
Number of Employee Absent (NA)	∑ Number of Employee Absent (NA)	23 people
Number of Total Employee (NE)	∑ NE	300 people
Health Level (HL)	1-(∑ NA / NE)	0,92333
Percent efficiency	(HL) x 100 %	92,33 %

Employee Training Level

From the data collection process, the results of calculating the efficiency of the training level are as follows: The calculation of the employee training level is based on a comparison between the number of employee training sessions or the number of employees who conduct training and the total number of employees during the period June 2022 to May 2023. The number of workers who attended training, the total number of employees, and the calculation of the employee training level are presented in Table 9. The number of workers who attended training during the period June 2022 to May 2023 was 161 people. The total number of workers involved in the company is 300 people. Employee Training Level (E_HRD) in lubricant manufacturing is 53.667% (Table 9).

Table 9. Calculation of employee training level

	Formula	Result
Number of Employee Training (NT)	∑ Number of Employee Training (NA)	161 orang
Number of Total Employee (NE)	∑ NE	300 orang
Employee Training Level (E_HRD)	1-(∑ NA / NE)	0,53667
Percent efficiency	(E_HRD) x 100 %	53,667 %

Table 10. Efficiency result obtained from data calculations based on the formula previously mentioned.

Weight of Lean & Green Perspective	Weight of Risk Perspectives	Aspect	Weight of Sustainability Aspect	Indicators	Weight of Indicators	Global Weight
0,5	0,5	Operational Aspect	0,5	Time	0,1667	0,0208375
				Quality	0,1488	0,0186
				Material	0,1845	0,0230625
		Environmental Aspect	0,22	Energy Consumption	0,0952	0,005236
				Water Consumption	0,0833	0,0045815
		Social Aspect	0,28	Satisfaction Level	0,1130	0,00791
				Health Level	0,1130	0,00791
				Employee Trainin Level	0,0952	0,006664

This weighting is calculated with BORDA method using scoring the questioner that filled by supervisor and jr. supervisor in each section such as Human Resources, Operational, Warehouse, Quality Inspector, receiving and hoarding, and Techniq (Table 10).

Table 11. The results of calculating the efficiency of all indicators of sustainability

Sustainability Aspect	Indicators	Efficiency Score (a)	Global Weight (b)	Manufacturing Sustainability Performance (∑ a x b)
Operational Aspect	Time	78,50%	0,0208375	83,128 %
	Quality	99,42%	0,0186	
	Material	98,90%	0,0230625	
Environmental Aspect	Energy Consumption	72,086%	0,005236	
	Water Consumption	69,187%	0,0045815	
Social Aspect	Satisfaction Level	96,667%	0,00791	
	Health Level	92,33%	0,00791	
	Employee Training Level	53,667%	0,006664	

The best efficiency level is the quality indicator of 99,42% and the lowest is the employee training level of 53,667% from the social aspect, and from the operational aspect is Time about 78,50%. Total Manufacturing Sustainability Score is 83,128% (Table 11).

The quality indicator is the third most crucial weight. Quality is the most critical indicator of sustainability. Manufacturing to ensure customer satisfaction. The findings of this study are consistent with those of Hartini et al. (Hartini et al. 2020). According to the findings of Lakatos et al. (Lakatos et al. 2021), product quality can influence customer satisfaction and purchase intent. As a result, businesses must devise strategies emphasizing product quality as a competitive advantage (Tyagi et al. 2015).

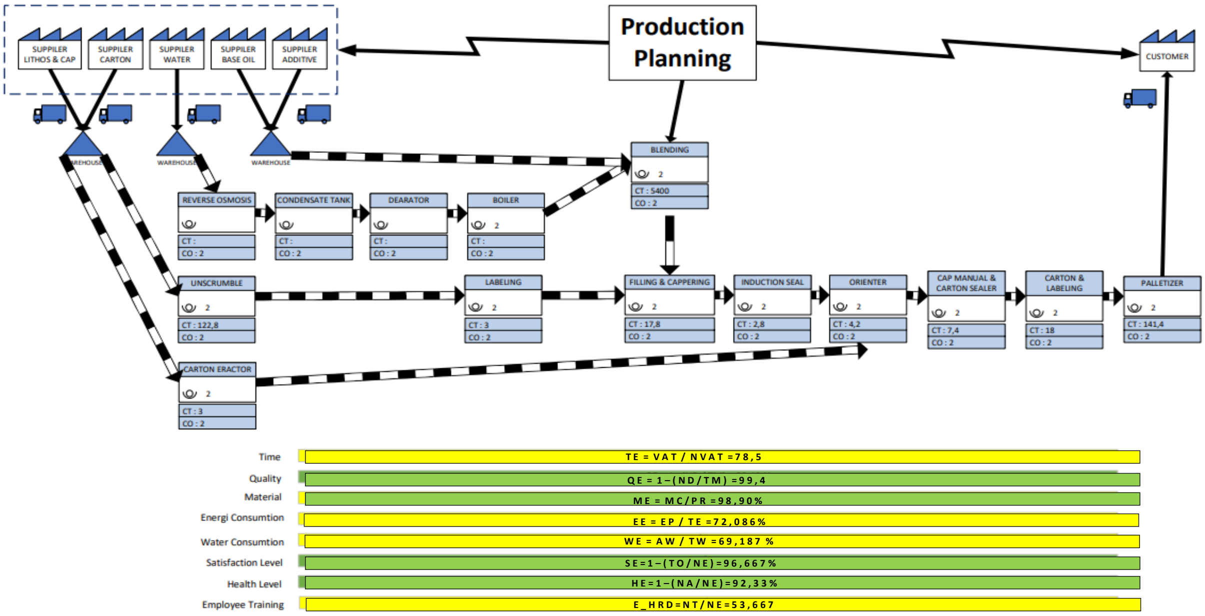

Figure 2. Mapping of SVSM

Conclusion

The primary goal of this research is to propose a new framework based on Risk mitigation and Lean methods for assessing sustainable manufacturing performance in a production line. This new framework has been successfully proposed to assess the performance of manufacturing sustainability in the production line. The proposed framework begins by selecting indicators, weighing indicators with BORDA, evaluating the efficiency of each indicator, and mapping SVSM. Then, each indicator’s weight and performance determine the manufacturing sustainability score. This framework is used in Indonesian lubricant manufacturing. The case study findings indicate that the manufacturing performance of the lubricant industry could be improved, especially in terms of time production, material consumption, and employee training level.

Recommendations

Several recommendations are given to manufacturers including the following: employee training enhancement, Improve the level of employee training through structured and comprehensive programs to enhance technical skills and process understanding; visualizing work procedures, Implement visual aids such as icons, signs, or guidelines for easy comprehension; process standardization, Create clear and easily-followed standard work procedures for each production stage; implementation of quality control tools, apply simple quality control tools like Pareto charts, cause-and-effect diagrams, and process flowcharts. These tools help identify root causes, focus on relevant improvements, and monitor progress.; and Set Key Performance Indicators (KPIs) and monitor them regularly

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

This article was presented as an oral presentation at the International Conference on Research in Engineering, Technology and Science (www.icrets.net) held in Budapest/Hungary on July 06-09, 2023.

References

Abdul-Rashid, S. H., Sakundarini, N., Raja Ghazilla, R. A., & Thurasamy, R. (2017). The impact of sustainable manufacturing practices on sustainability performance: Empirical evidence from Malaysia. *International Journal of Operations and Production Management*, *37*(2), 182–204.

Arliana, A. G., & Soebroto. A. A. (2018). Group decision support systems for corporate unit performance assessment using the TOPSİS and Borda methods. *Journal of Information Technology Development and Computer Science, 2* (12), 7348-7356.

Arifin, S., Soetjipto, W. J., & Qudsy, H. N. (2021). Analisis rsiko keterlambatan proyek Menggunakan metode house of risk. *Journal of Applied Civil Engineering and Infrastructure Technology, 2*(1), 19-26.

Bergmiller, G. G., & Mccright, P. R. (2009). Parallel models for lean and green operations. *Proceeding of the 2009 Industrial Engineering Research Conference*, (*Volume 1*, No: 1, pp. 22-26). Tampa, FL, USA: University of South Florida and Zero Waste Operations Research and Consulting.

Bogue, R. (2014). Sustainable manufacturing: A critical discipline for the twenty-first century. *Assembly Automation*, *34*(2), 117–122.

Christoffersen, L. B., Larsen, A., & Togeby, M. (2006). Empirical analysis of energy management in Danish industry. *Journal of Cleaner Production*, *14*(5), 516–526.

Duflou, J. R., Sutherland, J. W., Dornfeld, D., Herrmann, C., Jeswiet, J., Kara, S., Hauschild, M., & Kellens, K. (2012). Towards energy and resource efficient manufacturing: A processes and systems approach. *CIRP Annals - Manufacturing Technology*, *61*(2), 587–609.

Faulkner, W., Badurdeen, F., Templeton, W., & Gullett, D. (2012). Visualizing sustainability performance of manufacturing systems using sustainable value stream mapping (Sus-VSM) STEM education view project system level production modelling in coal mining industry view project. *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management*, 1–11.

Hartini, S., Ciptomulyono, U., Anityasari, M., & Sriyanto, M. (2020). Manufacturing sustainability assessment using a lean manufacturing tool: A case study in the Indonesian wooden furniture industry. *International Journal of Lean Six Sigma*, *11*(5), 957–985.

Huang, A., & Badurdeen, F. (2018). Metrics-based approach to evaluate sustainable manufacturing performance at the production line and plant levels. *Journal of Cleaner Production*, *192*, 462–476.

Ikatrinasari, Z. F., Hasibuan, S., & Kosasih, K. (2018). The Implementation Lean and Green Manufacturing through Sustainable Value Stream Mapping. *IOP Conference Series: Materials Science and Engineering*, *453*(1).

Joung, C. B., Carrell, J., Sarkar, P., & Feng, S. C. (2013). Categorization of indicators for sustainable manufacturing. *Ecological Indicators*, *24*, 148–157.

Jovane, F., & Westkämper, E. (2008). Towards competitive sustainable manufacturing. In *Springer*. Springer, Berlin, Heidelberg.

Lee, J. Y., Kang, H. S., & Noh, S. do. (2014). MAS2: An integrated modeling and simulation-based life cycle evaluation approach for sustainable manufacturing. *Journal of Cleaner Production*, *66*, 146–163.

Leong, W. D., Lam, H. L., Ng, W. P. Q., Lim, C. H., Tan, C. P., & Ponnambalam, S. G. (2019). Lean and green manufacturing—a review on its applications and impacts. *Process Integration and Optimization for Sustainability*, *3*(1), 5–23.

Mubin, A., Utama, D. M., & Nusantara, R. C. (2022). Manufacturing sustainability assessment comprising physical and mental workload: An integrated modified SVSM and AHP approach. *Process Integration and Optimization for Sustainability*.

Nawanir, G., Fernando, Y., & Teong, L. K. (2018). A second-order model of lean manufacturing implementation to leverage production line productivity with the importance-performance map analysis. *Global Business Review*, *19*(3), 114–129.

Oduoza, C. F. (2020). Framework for sustainable risk management in the manufacturing sector. *Procedia Manufacturing*, *51*, 1290–1297.

Pajunen, N., Watkins, G., Wierink, M., & Heiskanen, K. (2012). Drivers and barriers of effective industrial material use. *Minerals Engineering*, *29*, 39–46.

Pujawan, I. N., & Geraldin, L. H. (2009). House of risk: A model for proactive supply chain risk management. *Business Process Management Journal*, *15*(6), 953–967.

Rahman, N. A. A., Sharif, S. M., & Esa, M. M. (2013). Lean manufacturing case study with Kanban system implementation. *Procedia Economics and Finance*, *7*, 174–180.

Shah, L., Etienne, A., Siadat, A., & Vernadat, F. B. (2012). (Value, Risk)-based performance evaluation of manufacturing processes. *IFAC Proceedings Volumes (IFAC-PapersOnline)*, *45*(6), 1586–1591.

Soosay, C., Nunes, B., Bennett, D. J., Sohal, A., Jabar, J., & Winroth, M. (2016). Strategies for sustaining manufacturing competitiveness: Comparative case studies in Australia and Sweden. *Journal of Manufacturing Technology Management*, *27*(1), 6–37.

Suryanti, F., Sudiarno, A., & Sudarni, A. A. C. (2020). Combination of value stream mapping and house of risk methods to eliminate waste in productivity enhancement in production area of fertilizer company. *IOP Conference Series: Materials Science and Engineering*, *847*(1).

Swarnakar, V., Singh, A. R., Antony, J., Tiwari, A. K., & Cudney, E. (2021). Development of a conceptual method for sustainability assessment in manufacturing. *Computers and Industrial Engineering*, *158*. 107403.

Swarnakar, V., Singh, A. R., Antony, J., Kr Tiwari, A., Cudney, E., & Furterer, S. (2020). A multiple integrated approach for modelling critical success factors in sustainable LSS implementation. *Computers and Industrial Engineering, 150,* 106865.

Vinodh, S., ben Ruben, R., & Asokan, P. (2016). Life cycle assessment integrated value stream mapping framework to ensure sustainable manufacturing: A case study. *Clean Technologies and Environmental Policy*, *18*(1), 279–295.

Wiengarten, F., Fynes, B., & Onofrei, G. (2013). Exploring synergetic effects between investments in environmental and quality/lean practices in supply chains. *Supply Chain Management*, *18*(2), 148–160.

Author Information

Fara Kamila Hudy
Institute Technology of Sepuluh Nopember
Surabaya, Indonesia
Contact e-mail: *farakamilahudy@gmail.com*

Nidaru Ainul Fikri
Institute Technology of Sepuluh Nopember
Surabaya, Indonesia

Udisubakti Ciptomulyono
Institute Technology of Sepuluh Nopember
Surabaya, Indonesia

To cite this article:

Hudy, F.K., Fikri, N.A. &, Ciptomulyono, U. (2023). Integrated model of lean and risk mitigation for sustainability performance measurement in the lubricants manufacturing industry. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 23,* 452-463.