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Lean Sustainable Competitive Manufacturing Strategy Assessment: A Case Study in the Indonesian Car Manufacturing Company

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The scarcity of resources combined with the COVID-19 pandemic outbreak has forced the manufacturing companies to be more prudent in using their production resources such as raw materials, energy, and water. A lean sustainable production system is an effective Competitive Manufacturing Strategy (CMS) that enables companies to sustain their production by identifying the potential waste and pollution. This study aimed to propose a novel framework by combining Sustainable Value Stream Mapping (SVSM) by Hartini and Sustainability Index (SI) assessment model by Garbie to assess the contribution of lean sustainable CMS in enhancing manufacturing performance. An SVSM and pairwise comparison is used to measure the SI. The SVSM is applied to identify the waste, while the pairwise comparison is used to determine each performance indicator's weight. A case study is conducted in an Indonesian car manufacturing company to validate how the lean sustainable CMS improves the SI. The results of this study should guide the practitioners in a standard procedure for assessing the effectiveness of lean sustainable CMS. For academicians, the work provides empirical evidence of the positive impact of lean sustainable CMS practices on the SI.

1. Introduction

The deficiency of production resources, especially fossil energy (Chofreh et al., 2020), combined with the COVID-19 outbreak (Zeinalnezhad et al., 2020) and the government regulation (Goni et al., 2021), have forced the manufacturing companies regarding the sustainability issues in their daily production system. This problem also applies to car manufacturers (Sari et al., 2015), which are one of the many manufacturers that are struggling towards a sustainable supply chain (Chofreh et al., 2016). A Lean Production System (LPS) is one of the main Competitive Manufacturing Strategies (CMS) to become more sustainable (Garbie, 2016). Hartini et al. (2020) stated that Sustainable Value Stream Mapping (SVSM) is an effective tool of LPS for identifying improper manufacturing processes to avoid waste and pollution. Therefore, the company can define the room for optimal improvements in the utilisation of production resources sustaining profit, being environmentally benign, and safe for all stakeholders.

Choudhary et al. (2019) stated that LPS needs a tool named Value Stream Mapping (VSM) to evaluate its effectiveness in improving sustainable performance. Previous researchers have developed VSM. However, they are focused on partially sustainability factors rather than integrating all of them. It has been proved in the work of Edtmayr et al. (2016), which considered the economic and environmental factors in developing VSM to enhance green automotive manufacturer performance. They developed VSM concerning time, energy, waste, water, solvents, and CO_2 for evaluating the effectiveness of the three R basic strategies (reuse, recycle,

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recovery) in preventing waste and pollution and enhancing resources efficiency. Muñoz-Villamizar et al. (2019) proposed VSM that integrates an environmental perspective named Overall Greenness Performance (OGP) for VSM. This study conducted a case study in Spain automotive manufacturer for measuring performance concerning time, energy use, solvent use, and air emission. The results revelated that the integration of lean and green enables enhancing the manufacturing performance. However, their OGP-VSM does not consider physical work and environment work (social factor). Currently, Gholami et al. (2021) proposed a VSM that combines the lean, green, and six sigma methodologies to measure the performance of the Malaysian substrate manufacturing system concerning time and using of production resources (energy, water, and chemical).

Faulkner and Badurdeen (2014) are among the first authors to propose a comprehensive SVSM that considers six indicators for measuring the implication of the production process. The SVSM validated in the US satellite television dishes manufacturer that focused evaluating the use of production resources (time, raw material, energy, water), environmental burden, and physical effect of the worker. Hartini et al. (2020) developed a single framework that applied SVSM, Delphi Method, and Analytical Hierarchy Process approach to evaluate sustainable manufacturing performance in the Indonesian wooden furniture industry. This framework consists of 11 indicators related to conventional lean and three pillars of sustainability. Table 1 presents the identified VSM indicators in the manufacturing industry. It shows that all authors have considered economic and environmental factors in their VSM and social factors as emerging factors in developing VSM.

This study aimed to answer research questions on developing a simple and comprehensive tool measuring the contribution of lean CMS enhancing sustainable performance. To answer the issue, this study proposes an SVSM based on Hartini's model that considers three factors of sustainability and a methodology to assess the Sustainability Index (SI) based on Garbi's formula. The main advantage of this formula is that it does not require a normalisation process converting different measurement units into dimensionless scores. Therefore, it enables simplifying the performance measurement process (Garbie, 2016). The remaining paper is structured into four sections. Section 2 shows the research approach for assessing the SI. Section 3 discusses the results of this study. Finally, section 4 concludes this study.

Table 1: The SVSM indicators identified in the manufacturing industry

Authors	Cost					Environmental						Social			
	C1	C2	C3	C4	C5	E1	E2	E3	E4	E5	E6	S1	S2	S3	S4
Brown et al. (2014)	√					√	√		√				√	√	
Faulkner and Badurdeen (2014)	√					√	√		√				√	√	
Nallusamy et al. (2015)	√						√				√				
Edtmayr et al. (2016)	√						√	√	√	√	√				
Garza-Reyes et al. (2018)	√						√	√							
Hartini et al. (2018)	√	√	√	√		√	√	√		√			√	√	√
Choudhary et al. (2019)	√										√				
Gholami et al. (2019)	√												√	√	
Maqbool et al. (2019)	√														
Muñoz-Villamizar et al. (2019)	√				√		√			√	√				
Hartini et al. (2020)	√	√	√	√		√	√	√				√	√	√	√
Marie et al. (2020)	√			√		√	√						√	√	
Samant and Prakash (2020)	√	√				√					√				
Gholami et al. (2021)	√						√		√	√					
Viles et al. (2021)									√						
Selected indicators	√			√			√	√				√	√	√	√

Cost: ^{C1} Time; ^{C2} Cost; ^{C3} Inventory; ^{C4} Quality compliance and product defect; ^{C5} Changeover time
Environmental: ^{E1} Material consumption; ^{E2} Energy consumption; ^{E3} Waste recycling; ^{E4} Water consumption; ^{E5} Hazard material; ^{E6} Air pollution
Social: ^{S1} Satisfaction level; ^{S2} Work environment: noise level and lighting level; ^{S3} Physical work: activity with risk and lost workday; ^{S4} Employee training

2. Research approaches

This stage consists of two main sections concerning developing the measurement indicator and measuring steps of SI.

2.1 Defining the sustainable value stream mapping and sustainability index indicators

This section comprises three steps. First, the list of initial SVSM and SI indicators are elaborated based on the previous studies. This study categorised 15 initial indicators into three pillars of sustainability (see Table 1). Second, the initial indicators were validated by the experts through the interview process. The case study was conducted at an Indonesian car manufacturing company that produces Truck Colt Diesel (TCD). In this study, indicators related to planned maintenance program achievement are embedded (Sari et al., 2014). Third, this study selected 13 indicators based on the objectives, characteristics, and limitations of the case study company.

2.2 Creating current sustainable value stream mapping and measuring sustainability index

This section composes of two main processes. First, creating the current SVSM based on Hartini's study (Hartini et al., 2020). This SVSM considers the three factors of sustainability and uses a traffic light system. This system is used for classifying the actual achievement of each indicator and actions needed for improvement. The green colour explains that the actual achievement meets the target and can be further improved by a routine program. The yellow colour signs that actual achievement falls slightly below the target value, and corrective action is needed. The red colour explains that the actual achievement falls well below the target value and corrective action needs to be taken immediately. The management level determines the target value of each indicator.
Second, measuring the SI using Garbie's formula as following (Garbie, 2016).

- Rate the target value (S) of each indicator by the top management level.
- Rate the actual achievement value (E) of each indicator by top management level.
- Determine the value of change for each indicator (S – E).
- Calculating the SI for economic (SI_{Ec}), social (SI_{Sc}), and environmental (SI_{En}) factors - Eq(1) and Eq(2).

$$SI = \left(\frac{S_{i1}}{E_{i1}}\right)^{Yi1} x \left(\frac{S_{i2}}{E_{i2}}\right)^{Yi2} \dots x \left(\frac{S_{nij}}{E_{nij}}\right)^{Ynij} \quad (1)$$

$$Y_{ij} = log\left|S_{ij} - E_{ij}\right| \quad (2)$$

- Compute the relative importance weight (W) of factors by expert's judgment using Saaty's nine-point scale.
- Calculate the overall score of SI using Eq(3).

$$Overall\ SI = (W_{Ec}\ x\ SI_{Ec}) + (W_{Sc}\ x\ SI_{Sc}) + (W_{En}\ x\ SI_{En}) \quad (3)$$

3. Results and discussion

There are two main results of this study, i.e., current SVSM and overall SI for the case study company.

3.1 The current sustainable value stream mapping

This study developed an SVSM that consists of material and manufacturing process flow to identify Non-Value-Added Activity (NVA) and inefficiency of resources utilisation, as presented in Figure 1. The SVSM shows three main information related to time, Kaizen Burst, and dashboard actual achievement of each indicator.
The Kaizen burst reveals some waste and problems concerning economic (blue), social (yellow), and environmental (green) factors. In terms of the economy, the current SVSM identifies three waste (motion, defect, delay) and one problem, i.e., process time too long. There are three problems concerning social, i.e., PSW often failed, work position of operators is not ergonomic, and transportation without material handling. Regarding environmental, there are two problems, i.e., energy consumption too high and low lighting level.
The dashboard of actual achievement for each indicator is presented in three traffic lights colours. There are 4 out of 5 indicators below the target (yellow) regarded economic factor. Time is the main indicator of traditional lean manufacturing (Hartini et al., 2020). SVSM shows that the achievement of this indicator is 85 % out of 100 %. The actual achievement of the defect indicator is 13 % out of 4 %. The quality of raw material from suppliers achieved 80 % out of 100 %. Concerning the maintenance program, the company has executed 75 % of the planned maintenance program. It needs to be enhanced since a sustainable maintenance program enables optimising the use of production resources and impeding waste and pollution, specifically in the automotive industry (Sari et al., 2021). The compliance with quality standards and environmental regulations, the company

has been certified with ISO 9001:2008, ISO 9001:2015, ISO 14000, and IATF 16949:2016. The achievement of this indicator is 100 % (green). In terms of social factors, there are 3 out of 6 indicators below the target (activity with risk, noise level, and satisfaction level), and 3 out of 6 indicators have achieved the target named lost workday, lighting level, and employee training. All indicators fall well below the target value (red) concerning environmental factors, so they need to be solved immediately. First, energy consumption is needed for the production process. Edtmayr et al. (2016) stated that non-renewable energy consumption during the production process directly relates to GHG emissions. SVSM shows the energy consumption of the TCD falls well below the target value, i.e., 990 MJ. Second, wastewater that has been recycled is 60 %. Viles et al. (2021) stated that water is becoming a critical production resource, and the company needs to develop a strategy that enables water recycled 100 % to achieve a zero-waste strategy.

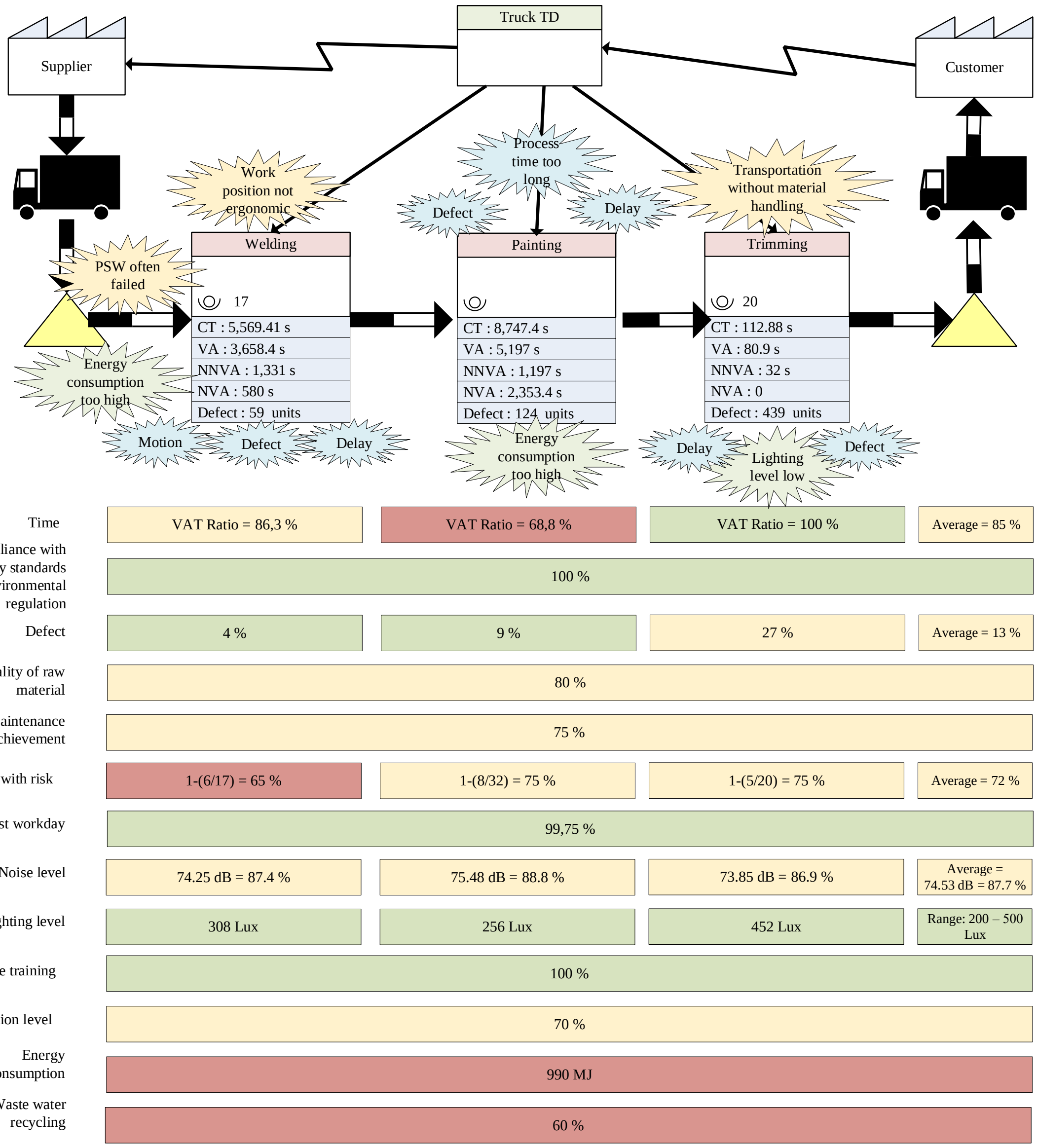

Figure 1: Current SVSM

3.2 The Sustainability Index

This section presents the SI achievement of the case study company, i.e., 79 % for economic, 312 % for social, and 188 % for environmental factors, as shown in Table 2. To calculate the overall SI, the management level of the case study company determined the relative importance of each factor, i.e., 0.74, 0.17, and 0.09 for economic, social, and environmental. Finally, the overall SI is 128 % which needs 1.28 times more effort concerning time and cost than exiting conditions to be sustainable.

Table 2: Sustainability index

Factor/ Indicator		% Measure	Actual	Target	Value of change	SI (Factor)	Eigen-vector	Overall SI
Economic	Time	%	85	100	15	79 %	0.74	128 %
	Compliance with quality standards and environmental regulation	%	100	100	0			
	Defect	%	13	4	9			
	Quality of raw material	%	80	100	20			
	Planned Maintenance program achievement	% (month)	75	100	25			
Social	Activity with risk	%	72	100	28	312 %	0.17	
	Lost workday	%	0.25	0	0.25			
	Noise level	dB	74.53	85	10.47			
	Lighting level	Lux	256 - 452	200 - 500	0			
	Employee training	Topics (month)	3	3	0			
	Satisfaction level	%	70	100	30			
Environ-mental	Energy consumption	MJ	990	900	90	188 %	0.09	
	Wastewater recycling	%	60	100	40			

4. Conclusions

This study proposed a simple and comprehensive SVSM framework for assessing the contribution of lean, competitive manufacturing strategy enhancing SI. The SVSM enables the identification of waste and the actual achievement of each indicator, then the actions needed for improving the overall SI can be formulated. The overall SI value for the case study company is 128 %. Moreover, two indicators concerning environmental, i.e. energy consumption and waste-water recycling, fall well below the target value (red zone), corrective action needs to be taken immediately to improve the achievement of these indicators.
The results of this study would advance the SVSM framework by providing a list of important indicators that need to be considered in assessing the contribution of LPS to become a more sustainable company. The authors will continue the study identifying the waste and proposes an improvement program. Next, the methodology for creating SVSM and calculating SI after improvement will be developed.
This study has limitations regarding the weight of each indicator since the weights are determined by the case study company experts. The standard weight of each indicator is thus required for a specific industry, and the future study can conduct a large survey to determine these weights.
Finally, this SVSM is developed based on the case of an Indonesian car manufacturing company. It can be used for other companies by reshaping the SVSM concerning their internal condition and external pressure.

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