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Development of a Lean and Green Indicators for Sustainability Assessment in Processing Manufacturing Industries: A Delphi approach



Abstract: - Sustainability has become a concern of academics and practitioners, where implementing sustainability can help reduce environmental impact, and for that, it is necessary to take steps to assess the level of sustainability. So to assess sustainability, it is necessary to discuss the indicators used to measure sustainability, where these indicators really need to be discussed in measuring sustainability manufacture. This paper aims to determine the selection of indicators used for sustainability assessment in the manufacturing industry by discussing lean and green indicators to measure sustainability. Given that lean focuses on operational performance while green focuses on environmental performance, these two dimensions will be examined for appropriate indicators to measure sustainability. The Delphi method is used in this study to select manufacturing sustainability indicators that are appropriate or relevant to the manufacturing industry. The findings of this study found 29 indicators suitable for measuring sustainability in the processing manufacturing industry, consisting of 13 indicators for the economic dimension, 9 for the environmental dimension, and 7 for the social dimension. The indicators obtained can be applied to measure sustainability in the cooking oil processing manufacturing industry.

Keywords: *Lean manufacturing, green manufacturing, sustainability manufacturing, Delphi method, sustainability indicator.*

I. INTRODUCTION

With increasing global competition, this puts pressure both on the flexibility of manufacturing firms and on the efficiency of resources to meet customer demands and competitiveness [1]. Manufacturing now faces challenges due to a scarcity of natural resources and urgent government rules to adopt new organizational or even manufacturing strategies. Manufacturing is required to produce high quality products at reasonable prices while reducing environmental impact [2] and having a major effect in achieving sustainability in society [3].

The need for sustainability assessment in manufacturing was recognized more than forty years ago. As demand pressures for sustainability increase in manufacturing companies, the drive to assess performance has strengthened [28]. However, at the time the concept emerged, the most focus was on environmental impact only, which gradually expanded to other pillars of sustainability (social) [4], [30] while the economic dimension was the flagship approach that was then followed.

The manufacturing industry continues to grow where sustainable manufacturing standards have been created called the "Sustainable Manufacture Toolkit" created by the Organization for Economic Cooperation and Development (OECD), where the OECD provides internationally accepted tools or indicators that are general to measure the environmental performance of manufacturing facilities in various business sizes, sectors or countries. According to the OECD, sustainable manufacturing is an exciting new way of doing business and creating value. "Sustainable manufacturing" is the formal name for an exciting new way of doing business and creating value. It is behind many eco-friendly products and processes that are in demand and celebrated around the world today. All types of businesses are already engaged in initiatives and innovations that help maintain a healthier environment,

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increase competitive advantage, reduce risk, build trust, drive investment, attract customers, and generate profits [29]. However, the existing indicators from the OECD are still general, not specific to which manufacturing industries are targeted. So it is necessary to follow up to make adjustments to this indicator can be applied in the refinery manufacturing industry.

For this reason, this paper aims to identify and select indicators that are in accordance with the manufacturing industry. The approach used with the Delphi method.

II. THEORY AND FORMULA

2.1 Sustainability

In the last three decades sustainability has become an increasingly emphasized subject, and is a more recent phenomenon that focuses on measuring sustainability performance based on published literature [5][27]. Sustainable development is defined by the World Commission on Environment and Development as "development that meets the needs of today without compromising the ability of future generations to meet their needs." [10]. According to Dornfeld [6] this definition includes two main concepts:

"The concept of 'needs', especially the essential needs of the world's poor, should be made a top priority.

The idea of the limitations caused by the state of technology and social organization to the ability of the environment to meet current and future needs."

To quote Lord Kevin in Dornfeld's book [6] "If you can't measure what you're making, you don't know if you're succeeding or not." We must be able to understand and measure the resources used in our products and their use. Then we can make informed decisions about its design, distribution, and utilization. This really drives us to think about the lifecycle costs of energy and consumables in the manufacture of a product—an important driver for green manufacturing.

2.2 Sustainable Manufacturing

The attention of researchers has focused on sustainable manufacturing i.e. to address various sustainability challenges in the manufacturing industry [7]. One of the most developed areas of research in recent times is sustainability manufacturing. The cause is gaining popularity among practitioners and researchers today due to the positive impact on sustainable performance and also the impact on manufacturing competitiveness, changes in the business environment, pressure from regulatory agencies to adopt environmental management (EM) strategies [3].

In assessing sustainability can be assessed by indicators through sustainability assessment methods [8]. In achieving the success of assessing sustainability, first define sustainability indicators clearly in accordance with the objectives and scope of sustainability assessment [9]. In this twenty-first century, companies not only focus on economic growth but pay more attention to environmental aspects to increase sustainable competitiveness so lean and green methods are needed for companies that want to be competitive and environmentally sustainable [10]. The integrated lean and green concept will promise to address the triple bottom line sustainability performance (TBL; economic dimension, environmental and social [11].

To achieve sustainability, it is necessary to assess the level of sustainability of the company, so it is necessary to identify the indicators used to assess. To improve sustainability practices in certain industries, it is necessary to assess the level of sustainability and become an important procedure [12]

1.3 Lean Manufacturing

The lean manufacturing paradigm will have an impact on organizations reducing lead times and production costs, better products, and faster delivery times, thereby increasing customer satisfaction and making organizations more competitive [13]. The importance of lean as a tool to eliminate waste, streamline processes, and increase added value [14][15].

1.4 Green Manufacturing

Today, the manufacturing industry faces challenges to comply with strict environmental regulations due to waste management issues, reduction of natural resources, and global warming. Increased concern and awareness about this issue is encouraging manufacturers around the world to adopt more environmentally friendly manufacturing practices [16].

In producing environmentally friendly products, manufacturing is the basis for an environmentally friendly manufacturing process. Obviously, industrial companies in adopting and implementing renewable manufacturing

practices face several challenges [17]. So many researchers to explore and develop the concept of "Green Manufacturing". In research Study [18] investigated the relationship between green manufacturing practices (GMP) and sustainable performance, driving factors and barriers in green manufacturing practices [16], In research [19] proposed a toolbox (Greenometer) to assess the greenness level of manufacturing companies. For this reason, it is necessary to develop the concept of green manufacturing concept.

1. Experimental setup

A structured set of triple bottom line (3BL) indicators is required to assess the sustainability of the manufacturing process [7]. According to Hartini et al [9] obtained 26 indicators that have been selected to assess sustainability in the furniture industry selected by researchers. In identifying relevant indicators used delphi method [20].

This study aims to identify and select lean and green indicators that are in accordance with the manufacturing industry to measure manufacturing sustainability or those that are in accordance with the triple bottom line (3BL) indicators. In this section, this research framework was developed according to the research objectives to select indicators that are in accordance with sustainable manufacturing in the cooking oil industry. The research framework can be seen in Figure 1. This research consists of four stages including: selection of TBL (Triple Bottom Line) indicators, making Delphi questionnaires, consensus analysis and Delphi feedback, then the final stage is the results consisting of a list of important TBL indicators in accordance with the manufacturing industry, this stage is also in accordance with [7]. This research was conducted by collecting and identifying previous studies that were in accordance with indicators in accordance with the Triple Bottom Line (economic, environmental, social), then prepared the first questionnaire to be distributed to experts, the response from the first questionnaire was the basis for conducting the second round of questionnaires.

The Delphi method is a way to gather input from experts, conduct conversations in a structured way [21]. According to Sourani and Sohail [22] the Delphi method is a reliable method among selected experts to be used to reach consensus. For this reason, this study uses the Delphi method to obtain indicators that are in accordance with the sustainability of cooking oil processing manufacturing.

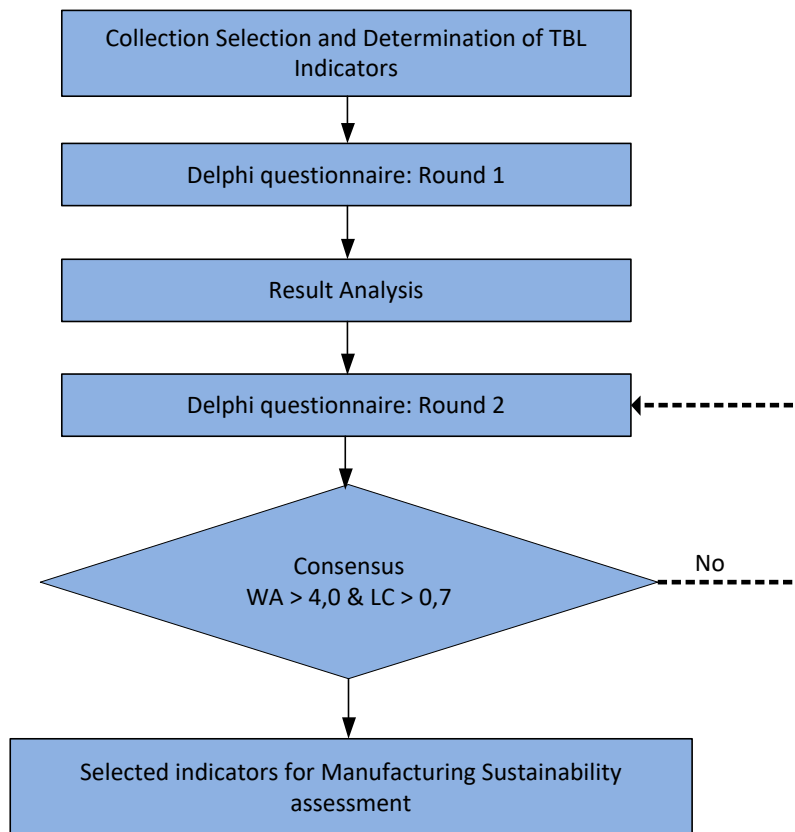


Figure 1. Research Framework

According to Abdul Shukor & Ng,[8] the elements in método delphi are expressed as follows:

Anonymity – Experts should be anonymous.

Iteration – A modified Delphi study must be conducted for at least two rounds in order for experts to reevaluate their responses until consensus is reached.

Controlled feedback – The content validity index for each statement should be calculated and all non-conforming statements removed.

Group answer aggregation – Researchers need to convert expert opinions into group consensus by providing the results of each round to experts.

To reach consensus, in this study using percentages for each question, percentages for the selection of scale categories '4 – relevan' and '5 – are very relevant'. The percentage must exceed 70% for the statement in a particular question to be acceptable. It is calculated based on the following equation:

$$\text{Persentase (\%)} = (\text{Number of experts choose scale category of 4 and 5} / \text{Total number of experts}) \times 100 \%$$

III. RESULT DISCUSSIONS

In this study conducted with the Delphi method by conducting two rounds of Delphi studies validated by fifteen experts. In the Delphi putran I stage, consensus is generally reached with values that meet the criteria. But there are some indicators that experts have different views on and need to consider. So that Delphi round II to confirm indicators that initially did not reach consensus in the first round was recommended to be included because it was in accordance with the refinery manufacturing industry. Thus, all indicators reach a consensus level with a high value.

Experts have reached an agreement to carry out the Delphi method with two rounds and agreed on the selected indicators according to the refinery manufacturing industry. In this study indicators were selected from experts based on previous studies. In the Step method of Delphi, indicators that obtain low values will be deleted or not selected. Then the selected indicators are classified on the basis of previous studies.

The following is a list of indicators corresponding to the refinery manufacturing industry based on the Delphi method. The results of indicators selected by the Delphi method are seen from the average value of each indicator.

1.1 Economic

In the economic dimension there are 13 indicators, where the indicators of material costs of products and electricity costs are the highest value seen in Figure 3. This result is very appropriate because the manufacturing industry is very concerned about the use of these two indicators. Furthermore, followed by indicators of labor costs, steam costs, manual labor utilization, water costs, maintenance costs, inventory costs, packaging costs, setup time, cycle time, lead time, waste disposal treatment costs.

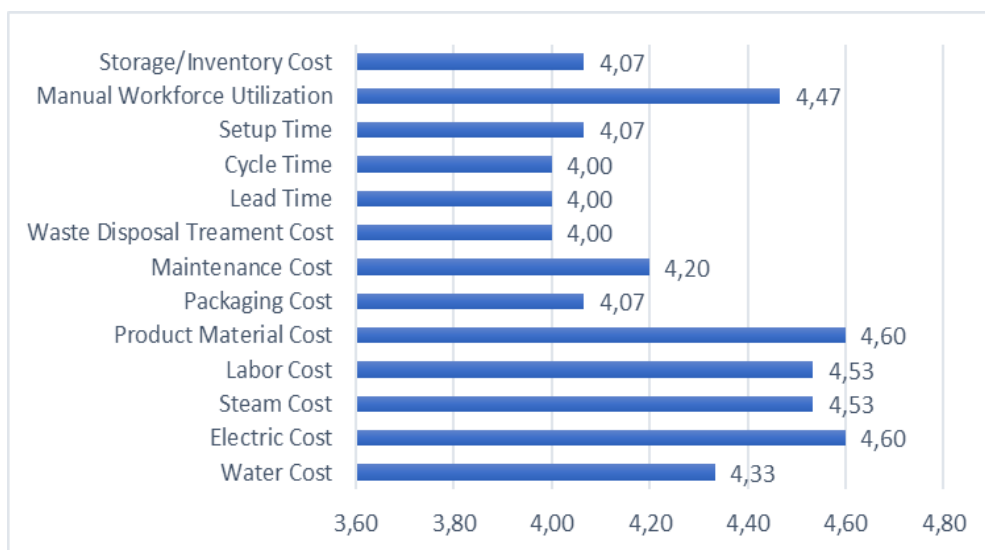


Figure 2. Mean score for economic dimension

1.2 Environment

In Figure 4. shows for environmental dimensions there are 9 selected indicators. The highest value indicators are the amount of steam, electricity usage and followed by other indicators such as the total weight of product raw materials, the total weight of packaging raw materials, the total amount of water consumed, the amount of solid waste generated, the amount of liquid waste produced, the amount of GHG, the percentage of packaging materials used.

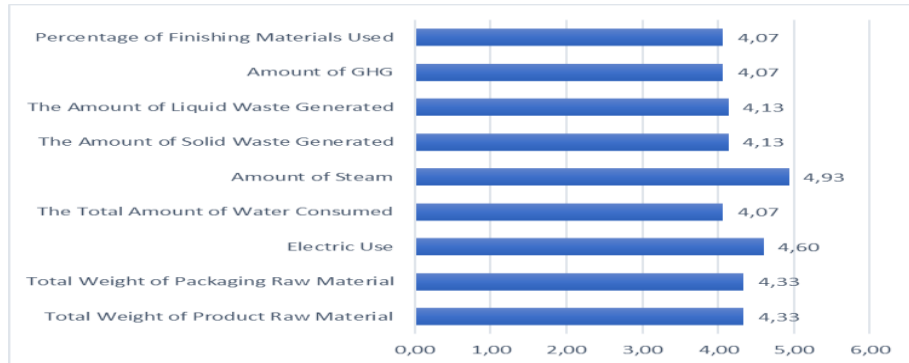


Figure 4. Mean score for environment dimension

1.3 Social

In Figure 5. Showing for the social dimension there are 9 selected indicators. The highest value indicators are employee training opportunities, then satisfaction level and followed indicators, lighting level, absence due to injury or illness, physical load index, noise level, injury level.



Figure 5. Mean score for social dimension

According to Hartini et al [9] and Utama et al [20] conducted a cut-off analysis in the selection of indicators assessed by 10 experts with a weighted average (WA) analysis of > 4.0 and a consensus level (LC) of > 0.7 on the sustainability indicators of furniture companies. The WA and LC formulas are presented in Equations 1 and 2. Furthermore, an assessment of the indicator by experts was carried out using five Delphi rating scales of scores (1) Very irrelevant, (2). Irrelevant, (3). Neutral, (4). Relevant, and (5). Very relevant. Based on the results of the questionnaire in the second round, the average value and consensus level can be seen in the Table 1.

Table 1. Results of the assessment of the relevance of each indicator.

No	Indikator	Tingkat Relevan					Wa	LC
		1	2	3	4	5		
1	Water Cost			1	8	6	4,33	0,93

2	Electricity Cost	1	4	10	4,60	0,93	
3	Steam Cost	1	5	9	4,53	0,93	
4	Labor Cost	2	3	10	4,53	0,87	
5	Product Material Cost	1	4	10	4,60	0,93	
6	Packaging Cost	1	2	7	5	4,07	0,80
7	Biaya Perawatan	2	8	5	4,20	0,87	
8	Waste Disposal Processing cost	1	3	6	5	4,00	0,73
9	Lead Time	1	2	8	4	4,00	0,80
10	Cycle Time	1	1	10	3	4,00	0,87
11	Setup Time	1	4	8	3	4,07	0,73
12	Manual labor utilization	2	4	9	4,47	0,87	
13	Storage / Inventory Cost	1	2	7	5	4,07	0,80
	Environment						
1	Total Weight of product raw materials	1	8	6	4,33	0,93	
2	Total Weight of packaging raw materials	2	6	7	4,33	0,87	
3	Electricity Use	1	4	10	4,60	0,93	
4	The total amount of water consumed	2	10	3	4,07	0,87	
5	Amount of Steam	8	10	2	4,93	0,80	
6	The amount of solid waste generated	3	7	5	4,13	0,80	
7	The amount of liquid waste generated	1	11	3	4,13	0,93	
8	Amount of GHG	4	6	5	4,07	0,73	
9	Percentage of packaging materials used	1	1	9	4	4,07	0,87
	Social						
1	Noise level	2	9	4	4,13	0,87	
2	Lighting Level		10	5	4,33	1,00	
3	Physical load index	2	8	5	4,20	0,87	
4	Injury rate	2	9	4	4,13	0,87	
5	Absence due to injury/illness	2	8	5	4,20	0,87	
6	Employee training opportunities	1	5	9	4,53	0,93	
7	Satisfaction level	1	1	3	10	4,47	0,87

After knowing the selected indicators for the refinery manufacturing industry, this paper also displays references to each selected indicator. For each indicator based on its reference and measuring units can be seen in Table 2. the following.

Table 2. Indicator and measurement units

	No	Indicator	Measurement Unit	Reference
Economic	1	Water Cost	Rp/Liter	[9],[5], [23],
	2	Electricity Cost	Rp/kWh	[9],[5],
	3	Steam Cost	Rp/Kg	Proposed
	4	Labor Cost	Rp	[5], [7], [24]
	5	Product Material Cost	Rp/unit	[5], [25], [23],
	6	Packaging Cost	Rp/unit	[5]
	7	Biaya Perawatan	Rp/unit	[5], [7]
	8	Waste Disposal Processing cost	Rp/Kg	[5]
	9	Lead Time	Minutes (min)	[5], [20], [9]
	10	Cycle Time	Minutes (min)	[5], [20], [9], [24]
	11	Setup Time	Minutes (min)	[5], [20], [9], [24]
	12	Manual labor utilization	%	[5]
	13	Storage / Inventory Cost		[5], [7], [9]
Environment	1	Total Weight of product raw materials	Kilograms (Kg)	[5], [25], [7], [9], [26]
	2	Total Weight of packaging raw materials	Kilograms (Kg)	[5],
	3	Electricity Use	mPt	[5], [9], [20], [7]
	4	The total amount of water consumed	Kilo watt hour (kWh)	[5], [24], [25], [7]
	5	Amount of Steam	Liters (L)	[5], [23], [7], [26]
	6	The amount of solid waste generated	Kg/Unit	[5], [7], [24], [26]
	7	The amount of liquid waste generated	Gallon/Unit	[5], [7], [25], [26]
	8	Amount of GHG	Kg/Unit	[5]
	9	Percentage of packaging materials used	%	[5], [7] [5]
Social	1	Noise level	dB	Proposed
	2	Lighting Level	lux	[5], [24], [23], [7]
	3	Physical load index	NA	[5], [24]
	4	Injury rate	%	[5], [23], [25]
	5	Absence due to injury/illness	%	[5], [7]

6	Employee training opportunities	%	[5], [7]
7	Satisfaction level	%	[5], [24], [7], [20], [9]

IV. CONCLUSIONS

This paper aims to identify sustainability indicators for the assessment of the refinery manufacturing industry. This paper by identifying previous studies related to sustainability indicators. Then the selection of indicators with the Delphi method approach was carried out so that the purpose of this paper was achieved to select sustainability indicators.

From the results of the study, 29 indicators were obtained by conducting the two-round delphi method. The selected indicators include 13 indicators for the economic dimension, 9 indicators for the environmental dimension and 7 indicators for the social dimension. By knowing the indicators of sustainability indicators so that they can assess the level of sustainability, especially in the manufacturing industry, processing. The results of the research provide input to academics and practitioners to be able to apply and develop manufacturing sustainability assessments.

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