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Interrelationship of Green Supply Chain Management (GSCM) Performance Indicators for Palm Oil Industry in Indonesia

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Interrelationship of Green Supply Chain Management (GSCM) Performance Indicators for Palm Oil Industry in Indonesia

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Abstract. This study identifies GSCM Performance indicators for the palm oil industry in Indonesia, analyse the relationships between these indicators, and classify those indicators. Literature studies and expert surveys are carried out and produce eleven indicators. Interpretative Structural Modelling is used as a method for modelling the relationships between these indicators and results in six indicators at the first level, namely water usage (G1), material usage (G9), global warming potential (G4),% CPO certified (G8), energy usage (G2),% product with take-back policies (G11); four indicators are at the second level: waste generated before recycled (G3), acidification potential (G10), COD (Chemical oxygen demand) (G6),% waste reused (G7); third level one indicator, namely (biological chemical demand) (G5). Meanwhile MICMAC Analysis was used to classify eleven performance indicators and produced nine indicators into cluster I, autonomous indicators, namely: energy usage (G2), waste generated before recycled (G3), BOD (biological chemical demand) (G5), COD (Chemical oxygen demand) (G6),% waste reused (G7),% CPO certified (G8), material usage (G9), acidification potential (G10),% product with take-back policies (G11). One indicator is cluster II, autonomous indicators, namely global warming potential (G4). For cluster III, linkage indicators, there are no indicators included in it at all. The last one indicator entered cluster IV, independent indicators, namely water usage (G1). In the end, this study give contribution to expand the using of ISM modelling especially for palm oil industry.

1. Introduction

The palm oil industry is a very important industry for Indonesia. This can be seen from the huge amount of production and export value over the past three years. In 2016 Indonesia produced 35.57 million tons of palm oil, then rose 18 percent to 41.98 million tons in 2017 [1]. While in 2018, until November alone the production had reached 43.75 million tons [2]. The export value of Indonesian palm oil in 2016 reached 18.22 billion US dollars, then rose 26 percent to 22, 97 billion United States dollars in 2017 [3]. While in 2018 the export value of the palm oil industry is projected to decline to US $ 19.50 billion [4]. Amid the rapid development, the oil palm industry has a lot of challenges that are getting bigger. European and American consumers for example demand that palm products must be more "green", in the sense of paying attention to the environment in each supply chain. The European Parliament

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unilaterally banned the use of palm oil-based biofuels in 2021 [5]. Previously the European parliament banned the use of palm oil in 2020 because it was considered a cause of deforestation. These challenges require the palm oil industry to operate more "green" or sustainable in its supply chain.

Green supply chain management (GSCM) is currently being debated between practitioners and academics. Environmental awareness is a driving factor in the revolution of human thought, where the whole world unites to reduce emissions produced in economic activity [7]. GSCM even developed at the conclusion that requires companies to integrate environmental thinking into the entire supply chain [8]. Many researchers wrote the results of their research on GSCM, including Jabbour et al [9] who wrote about the adoption of GSCM practices that affect environmental and operational performance; Jayaram et.al [10] who developed the GSCM framework using grounded theory and data support that tried to find a relationship between environmental policy emphasis and customer issues, sustainability strategy, and green supply chain design; Maditati et al [11] who compiled the conceptual GSCM framework from the review process of previous journals; Khan et.al. (2018) [12] which analyses the relationship between green logistics and energy demand, environmental factors, and economic health factors; Sharma et al [13] which identifies GSCM indicators on agro-industry and ranks them using analytical hierarchy process, Majumdar et.al. (2018) [14] which analysed the obstacles of green textile supply chain management in south-east Asia using structural modelling interpretations. However, these existing studies have not yet specifically analysed the relationship between GSCM performance factors in the palm oil industry in Indonesia. There is no study before it that use ISM Modelling to cope with palm oil industry.

This study is intended to identify key performance indicators that affect the GSCM palm oil industry in Indonesia, then analyse the relationships between these indicators using the ISM Model. ISM is a well-established technique for identifying relationships between specific elements that define a particular problem or issue [15]. MICMAC Analysis was then developed to classify these indicators based on driving and dependence power.

2. Methodology

The objective of this research can be achieved by the Interpretative Structural Modelling (ISM) method whose stages of preparation can be seen in figure 1. ISM is an interactive learning process where a set of different factors and factors that are directly related are structured into a comprehensive systematic model. The model that is formed, describes the structure of a complex problem or issue, a system or field of study, carefully designed its patter in the form of garments and words. The basic idea of the ISM is to use the opinions and knowledge of experts to decompose complex systems into several sub-systems and organize multilevel structural models. ISM helps to identify complex directions and relationships between elements in the system [16][17].

2.1. Literature Review

Kusrini et al. (2018) [18] in a previous study conducted literature review, then reviewed the principles of ISPO (Indonesian Sustainable Palm Oil) and RSPO (Roundtable on Sustainable Palm Oil), and finally conducted a survey to experts to produce 29 Sustainable Supply Chain Management Performance Indicator for the palm oil industry in Indonesia that divided into three categories namely economic, environmental, and social. The environmental category of the performance indicators was adopted as GSCM performance indicators in this study, in detail can be seen in Table 1.

2.2. Structural Self-Interaction Matrix (SSIM)

The Structural Self-Interaction Matrix (SSIM) is filled by experts who have worked in the palm oil industry in Indonesia. Based on the expert's opinion, the contextual relationship between GSCM indicators of the oil palm industry in Indonesia is made, in detail can be seen in Table 2. Four symbols are used as a sign of the direction of the relationship between indicators (i and j):

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V: i indicator will help achieves indicator j;
A: Indicator j will help achieve indicator i;
X: Indicators i and j will help achieve each other; and
O: Indicator i and j are unrelated.

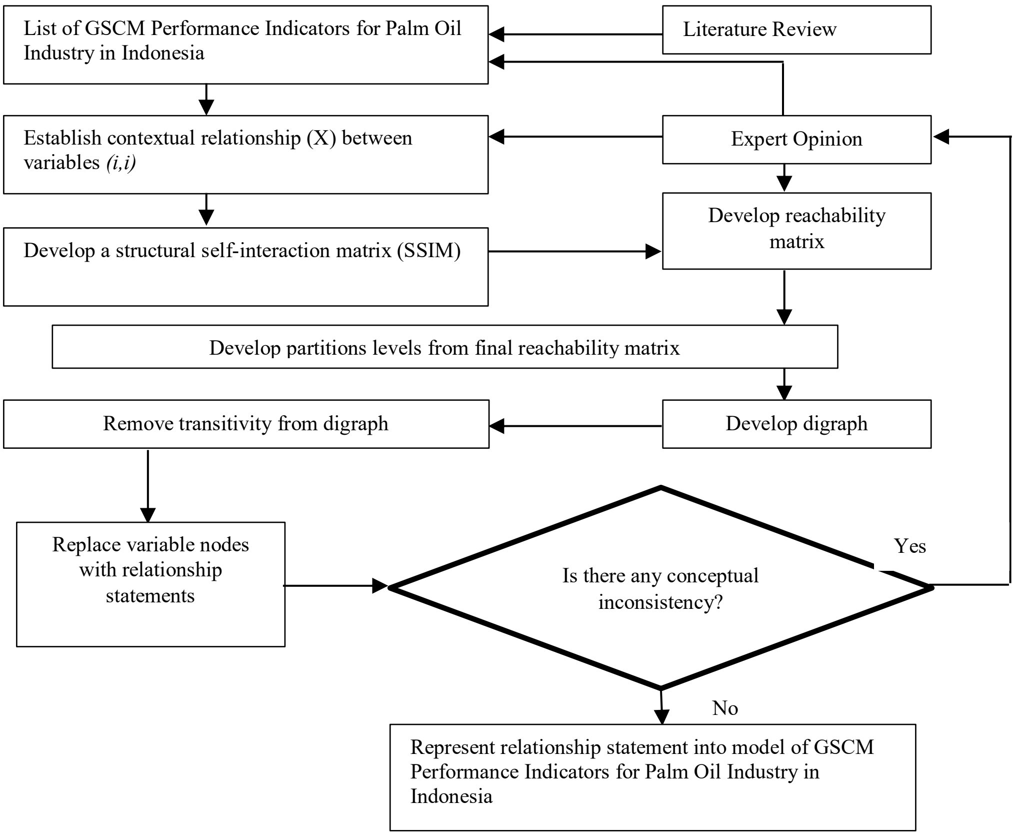

Figure 1. Flow diagram for preparing ISM Model

Table 1. GSCM performance indicators for palm oil industry in Indonesia

PI Code	Performance Indicators
G1	Water Usage
G2	Energy Usage
G3	Waste Generated Before Recycled
G4	Global Warming Potential
G5	BOD
G6	COD
G7	% Waste Reused
G8	% CPO Certified
G9	Material Usage
G10	Acidification Potential
G11	Percent Product with Take-Back Policies

In Table 2, Table 3, Table 4, and Table 5 is used PI Code, it means performance indicators code, just to make it simple. It shows G1 until G11 for performance indicators, G1 indicates GSCM indicators number 1. All can be seen in table 1. In table 2, it shows "0" for the meet of G1 rows and G11 column. It means performance indicators water usage (G1) with percent product with take back policies (G11) unrelated. This is example how we read the output of Table 2.

2.3. Reachability Matrix

Now the initial reachability matrix that forms the binary matrix is composed of SSIM by replacing V, A, X, O with numbers 1 and 0 by following these rules:

(i) If V appears in (i, j) an element in the SSIM, then 1 will be written in (i, j) element and 0 will be written in (j, i) element in the reachability matrix.
(ii) If A appears in (i, j) an element in the SSIM, then 0 will be written in (i, j) element and 1 will be written in (j, i) element in the reachability matrix.
(iii) If X appears in (i, j) an element in the SSIM, then 1 will be written in (i, j) element and 1 will be written in (j, i) element in the reachability matrix
(iv) If O appears in (i, j) an element in the SSIM, then 0 will be written in (i, j) element and 0 will be written in (j, i) element in the reachability matrix.

Table 2. SSIM Matrix

PI code	G11	G10	G9	G8	G7	G6	G5	G4	G3	G2
G1	O	O	O	O	V	O	O	O	V	O
G2	O	V	O	O	O	O	O	V	O	
G3	O	V	V	O	V	O	O	V		
G4	O	A	O	O	A	A	A			
G5	O	V	O	O	O	O				
G6	O	O	O	O	O					
G7	O	O	O	O						
G8	O	O	O							
G9	O	O								
G10	O									
G11										

Table 3. Initial Reachability Matrix

PI code	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
G1	1	0	1	0	0	0	1	0	0	0	0
G2	0	1	0	1	0	0	0	0	0	1	0
G3	0	0	1	1	0	0	1	0	1	1	0
G4	0	0	0	1	0	0	0	0	0	0	0
G5	0	0	0	1	1	0	0	0	0	1	0
G6	0	0	0	1	0	1	0	0	0	0	0
G7	0	0	0	1	0	0	1	0	0	0	0
G8	0	0	0	0	0	0	0	1	0	0	0
G9	0	0	0	0	0	0	0	0	1	0	0
G10	0	0	0	1	0	0	0	0	0	1	0
G11	0	0	0	0	0	0	0	0	0	0	1

After the initial reachability matrix is formed as shown in Table 3, followed by forming the final reachability matrix. Final reachability matrix is done by checking its transivity. Transivity indicates that if three variables are X, Y, Z and if variable X is related to variable Y and variable Y is related to variable Z, then variable X must be related to variable Z. Initial reachability matrix is validated by that transivity rule. The result of the validation is the final reachability matrix which can be seen in Table 4.

In Table 4, the meet of G1 row and G4 column was changed where in initial reachability matrix (Table 3), it shows "0" then in final reachability matrix (table 4) change to "1". It is effect of transivity rule where G1→G3→G4, G1 affect to G3, and G3 affect to G4, then G1 must affect to G4. So, "0" must be changed to "1". This is example of how we read the change of Table 4 from Table 3.

Table 4. Final Reachability Matrix

PI code	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	Driving Power	Rank
G1	1	0	1	1	0	0	1	0	1	1	0	6	I
G2	0	1	0	1	0	0	0	0	0	1	0	3	III
G3	0	0	1	1	0	0	1	0	1	1	0	5	II
G4	0	0	0	1	0	0	0	0	0	0	0	1	V
G5	0	0	0	1	1	0	0	0	0	1	0	3	III
G6	0	0	0	1	0	1	0	0	0	0	0	2	IV
G7	0	0	0	1	0	0	1	0	0	0	0	2	IV
G8	0	0	0	0	0	0	0	1	0	0	0	1	V
G9	0	0	0	0	0	0	0	0	1	0	0	1	V
G10	0	0	0	1	0	0	0	0	0	1	0	2	IV
G11	0	0	0	0	0	0	0	0	0	0	1	1	V
Dependence	1	2	2	8	1	1	3	1	3	5	1		
Rank	V	IV	IV	I	V	V	III	V	III	II	V		

2.4. Level Partitions

The reachability and antecedent set are obtained from the final reachability matrix [16]. The reachability set consists of the variable itself and other variables, which it may help achieve. While the antecedent set consists of the variable itself and other variables, which may help in achieving it. Intersection sets are variables that come out in the reachability set and antecedent sets at once [19]. Start second iteration and then, delete all variables whose numbers are in reachability set, when the variable is deleted in reachability set in the iteration, all components are also deleted in the reachability set, antecedent set, and remaining intersection sets. The level reach reachability matrix can be seen in Table 5.

Performance indicators that faded after first iteration; G1, G9, G4, G8, G2, and G11 be seen as level I in Table 5, then performance indicators that faded after second iteration such as G3, G10, G6, and G7 be seen as level II, and G5 the only performance indicator in third iteration be seen as level III.

3. Develop Model of GSCM Performance Indicators for Palm Oil Industry in Indonesia

3.1. Digraph and ISM-Model

The initial digraph is arranged with all relationships depicted with arrows, then final digraph by removing transitive, the results of which appear in Figure 2. While for level I, II, III, the results of partition level are adjusted Level I is at the top. After digraph is formed, the symbol number is replaced by a performance indicator and produces an ISM-based model that appears in Figure 3.

Table 5. Level Partition Reachability Matrix

PI Code	Reachability Set	Antecedent Set	Intersection Set	Level
		First Iteration		
G1	1	1,3,4,7,9,10	1	I
G2	2	2,4,10	2	I
G3	1,3	3,4,7,9,10	3	
G4	4	1,2,3,4,5,6,7,10	4	I
G5	4,5,10	5	5	
G6	4,6	6	6	
G7	4,7	1,3,7	7	
G8	8	8	8	I
G9	9	1,3,9	9	I

PI Code	Reachability Set	Antecedent Set	Intersection Set	Level
G10	4,10	1,2,3,5,10	10	
G11	11	11	11	I
		Second Iteration		
G3	3	3,7,10	3	II
G5	5,10	5	5	
G6	6	6	6	II
G7	7	3,7	7	II
G10	10	2,3,5,10	10	II
		Third Iteration		
G5	5	5	5	III

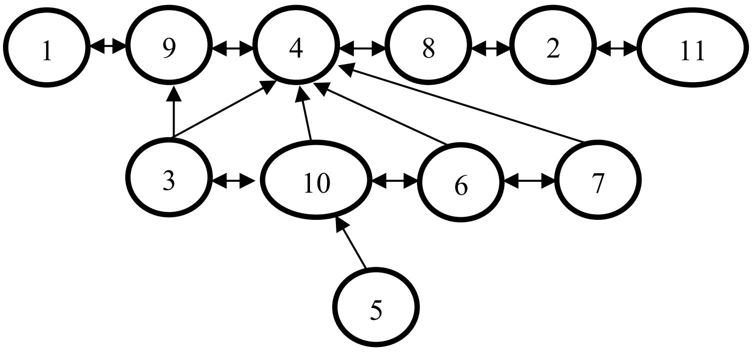

Figure 2. Digraph GSCM performance indicators for palm oil industry in Indonesia

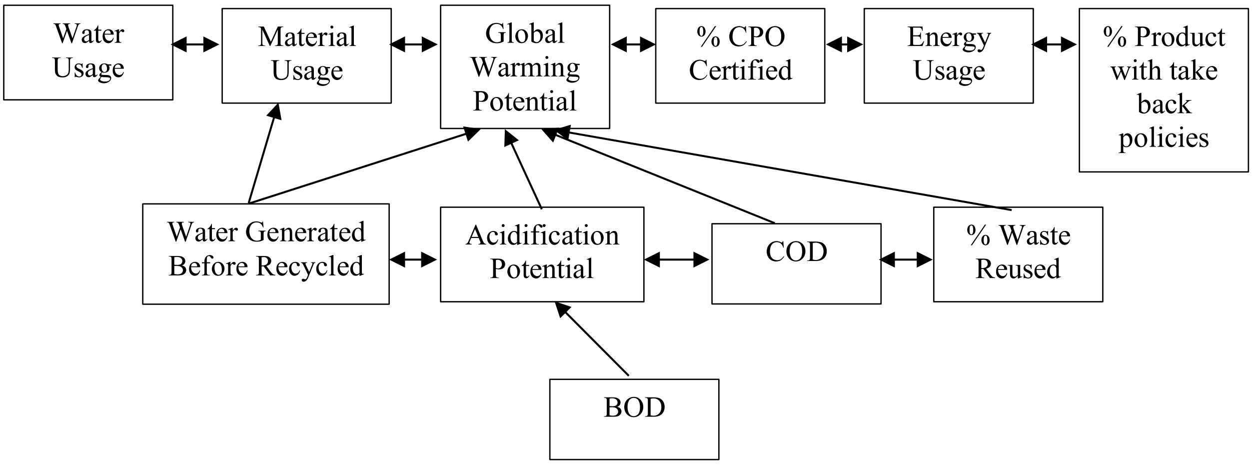

Figure 3. ISM-based model GSCM performance indicators for palm oil industry in Indonesia

3.2. Classification of Indicators

The driving power and dependency classification of each indicator uses MICMMAC analysis, a method developed by Duperin and Godet which is popularly known as "Cross-impact matrix multiplication applied to classification" [20]. The value of driving power and dependence is combined with the final reachability matrix as shown in Table 4. While the power-dependence driving diagram can be seen in Figure 4. Each indicator is classified into four clusters, namely:

- Cluster 1: Autonomous Indicators: These indicators have less dependence and less driving power. They tend not to be related to other indicators.
- Cluster 2: Dependent Indicators: These indicators have strong dependencies but weak driving power

- Cluster 3: Linkage Indicators: These indicators have high dependencies while high driving power.
- Cluster 4: Independent Indicators: indicators that have a weak dependency but high driving power.

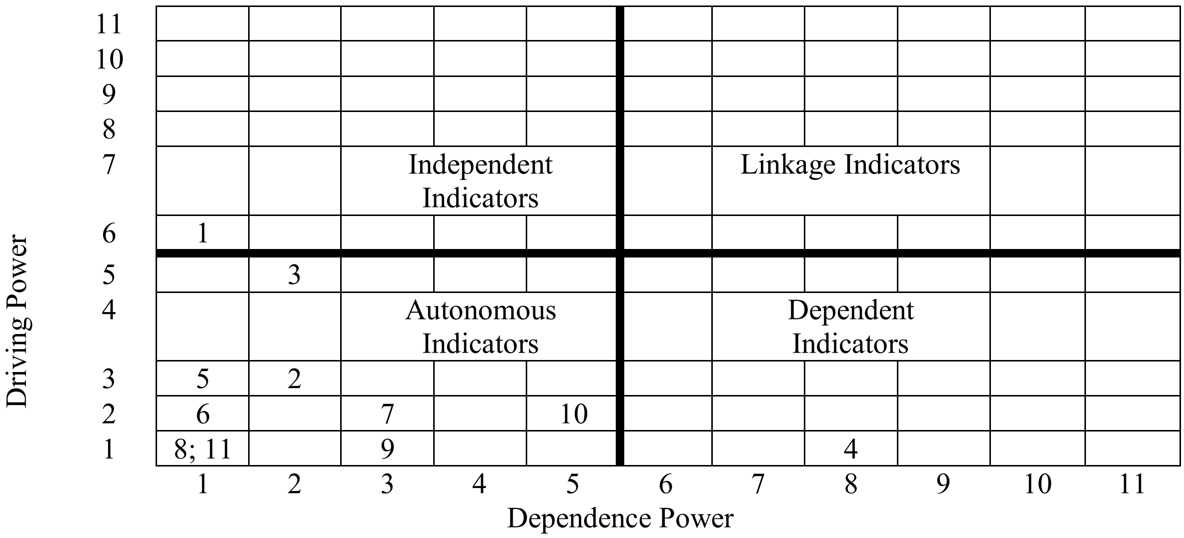

Figure 4. Driving Power-Dependence Diagram

4. Discussion and Conclusions

Eleven green supply chain management performance (GSCM) palm oil industry indicators in Indonesia were successfully identified through literature studies and surveys to experts. Eleven performance indicators include water usage (G1), energy usage (G2), recycled (G3) generated waste, global warming potential (G4), BOD (biological chemical demand) (G5), COD (Chemical oxygen demand) (G6), procentage waste reused (G7), procentage CPO certified (G8), material usage (G9), acidification potential (G10), procentage product with take-back policies (G11).

The ISM model then results from eleven performance indicators, of which six indicators are at the first level, namely: water usage (G1), material usage (G9), global warming potential (G4), procentage CPO certified (G8), energy usage (G2), procentage product with take-back policies (G11). At the second level there are four indicators: waste generated before recycled (G3), acidification potential (G10), COD (Chemical oxygen demand) (G6), procentage waste reused (G7). While the third level is only one indicator, BOD (biological chemical demand) (G5).

The last eleven performance indicators were classified into four clusters where nine of them entered cluster I, autonomous indicators, namely: energy usage (G2), waste generated before recycled (G3), BOD (biological chemical demand) (G5), COD (Chemical oxygen demand) (G6), procentage waste reused (G7), procentage CPO certified (G8), material usage (G9), acidification potential (G10), procentage product with take-back policies (G11). In cluster II, dependent indicators, only one indicator is included, namely global warming potential (G4). For cluster III, linkage indicators, there are no indicators included in it at all. Cluster IV, Independent indicators, also only one indicator, namely water usage (G1).

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