Environmental Sustainability Drivers: A Study on Malaysian Palm Oil Industry

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Abstract

Industrial practitioners and policy makers in the Malaysian palm oil industry are now focusing on understanding the factors that influence sustainability of palm oil supply chain network involving the fundamental principle of triple bottom line of social, environmental, and economic performance impacts of supply chain network design. In order to achieve sustainable products, an interpretive structural modelling approach method was used to better understand the drivers related to environmental sustainability reporting in the supply chain network related to the Malaysian palm oil industry. This paper has identified nine (9) environmental sustainability drivers (environmental management, life cycle assessment, green labelling, GHG emissions, climate change, energy efficiency, renewable resources, water, soil and air quality and lastly waste management) and the relationships between them. The findings from the environmental sustainability reporting drivers of this study can be furthered use to explore the potential impacts of supply chain network design on sustainability using the Malaysian palm oil industry as a reference. The novelty of this research is that it identifies the significance of environmental sustainability reporting based on the analyzed drivers and provides evaluation of environmental sustainability criteria's. This paper has provided a structural model of environmental sustainability and its associated method was developed by using the interpretive structural modeling model to determine the potential drivers in environmental sustainability reporting.

Keywords: life cycle assessment, sustainability analysis, sustainability reporting, triple bottom line

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1. Introduction

With the rapidly growing world population, the demand for palm oil is increasing. Among the 17 world major oils and fats, palm oil has made impressive and sustained growth in the global market. In 2008, palm oil accounted for 54% of the world's production of oils and fats; it is projected that palm oil will become the leading oil in the world around year 2016 (Oil World 2009). Malaysia is the world's second largest producer and exporter of palm oil after Indonesia; in 2007 it produced about 15.8 million tons of palm oil. In year 2020, production is forecast to increase to 18.5 million tons (Oil World 2009). Key challenges to the palm oil industry include misconceptions on palm oil sustainability and awareness of its potential in the global vegetable oil market, consumer demands for certification of products and processes and the competitiveness on the triple bottom line performances as uncertainties to the supply network.

Sustainability of palm oil is important if this versatile crop is to become the leading vegetable oil in the world. This multipurpose vegetable oil needs to be cultivated to ensure sustainable development from the environmental, social and economic aspects. With the world's population expected to increase to 8 billion in 2028, palm oil has the potential to be the source of fats and vegetable oil to feed the people around the globe (Basiron 2006; Basiron 2009). As high demand of cheap and quality vegetable oil is needed to feed the world's growing population, building a tool to improve the performance of sustainability of the palm oil supply chain network involving real-time data is necessary in order to achieve sustainable production. In this context, all parties involved with palm oil like plantation owners, financial institutions and banks, manufacturers of palm oil products and governments play an active role to realise this win-win situation for all. Hence, the time has come for all parties to co-operate and realise a sustainable production and development of palm oil. Ideas and efforts will become futile if all parties do not take an active and responsible role towards this aim as sustainable development of palm oil requires collaboration and initiative among the stakeholders.

Sustainability is also particularly important when it comes to the production of food, especially commodities that are widely used by the global food industry. The need to produce palm oil sustainably has led to the establishment of the Round Table on Sustainable Palm Oil (RSPO 2005). This roundtable is a platform to reach mutual understanding at the international level among various palm oil stakeholders namely; oil palm growers, palm oil processors/traders, consumer goods manufacturers, retailers, investment organizations, social or development Non-Governmental Organizations and environmental or nature conservation Non-Governmental Organizations. This understanding would be translated into common actions towards achieving sustainability of palm oil production and used in its entire supply chain. The Round Table on Sustainable Palm Oil has progressed towards formulating a set of principles and criteria for sustainable production, but has yet to implement a scheme to enable sustainably produced palm oil to be certified with full traceability. It is not easy to implement such an ambitious scheme, since maintaining the chain of custody for traceability purposes will be difficult and expensive. The importance of studying these environmental, social and economic issues, such as land conversions, productivity and environmental problems were also addressed by Sustainable Agriculture Initiative Platform and Sustainable Food Lab in Short Guide to Sustainable Agriculture documents. This is particularly important with the increased awareness of the environmental, social and economic issues as one of the key factors which influence consumer's perception towards sustainability in markets such as Europe.

1.1. Sustainability SWOT Analysis of the Malaysia Palm Oil Industry

SWOT analysis is an important support tool for decision-making, and is commonly used as a means to systematically analyse an organisation internal and external environments (Kangas et al. 2003; Kotler 1988). By identifying its strengths, weaknesses, opportunities, and threats, the organisation can build strategies upon its strengths, eliminate its weaknesses, and exploit its opportunities or use them to counter the threats. Strengths, weaknesses, opportunities and threats of the Malaysian palm oil industry in its present state from the SWOT analysis are presented in Figure 1.

Strengths	**Weaknesses**
-The Malaysian palm oil industry is considered the second largest in the world after Indonesia. -The Malaysian palm oil industry is greatly supported by its local government. -Palm oil itself is a resource that is used for the production of diverse products (part of agricultural diversifications). -Geographical diversifications.	-Poor performance of plantation segments. -Changes in the weather patterns worldwide can affect Malaysia's palm oil plantation and production.
Opportunities	**Threats**
-The support of the country's government and agencies to the industry in research findings. -Increasing demand of biofuels derived from palm oil and other plantation biomass which can be used as alternatives to fossil fuels such as diesel. [Palm oil gives high yields at low prices and is likely to be important in availability for future expansion for palm oil plantation.	-Shortage of labor is one of the main threats of the palm oil industry in Malaysia. -The palm oil industry in Malaysia faces significantly growing competition with other foreign producers. -The country is also experiencing lower land meeting biofuel demand].

Figure 1. SWOT Analysis for Malaysia palm oil industry (MPOB 2009; MPOC 2007; MPOB 2007).

The preliminary study of SWOT analysis was done to build understanding of the supply network in the Malaysia palm oil industry sector by carrying out semi-structured interviews. The objective was to review the literatures from academic and industrial viewpoints on the development of palm oil industry in Malaysia and categorise the findings into strengths, weaknesses, opportunities and threats and as well as in the form of semi-structured interviews. The interviews based on the semi-structured questionnaire were used to identify current practices in the Malaysian palm oil industry. This semi-structured questionnaire was designed to collect information related to the Malaysian palm oil industry. Three respondents from the Malaysia Palm Oil Board and Environmental Technology Research Centre, and the Standards and Industrial Research Institute of Malaysia (SIRIM) were interviewed. In the development of semi-structured questionnaire, key issues of interest were:

i) Topics of common issues or conflicts in the Malaysian palm oil industry;

ii) Environmental and social issues in the palm oil plantations;

iii) Environmental impacts and the sustainability initiative for sustainable palm oil production;

iv) Meeting consumer demands and requirements; and

v) Information and knowledge management throughout the supply network.

From the inputs of these interviews, data and information related to the palm oil industry corresponding to the research topic in Malaysia can be used for a better understanding of the supply network sustainability issues. The impacts to the global operations of the Malaysian palm oil industry were listed:

(i) The exposure of palm oil plantation areas to extensive impact of weather changes;

(ii) Lack of promotion on nutritional value and health benefits of palm oil and other global markets for Malaysian palm oil companies;

(iii) Research and development were conducted by government agencies rather than palm oil companies whereas the palm oil companies should continuously conduct their own researches and improve their respective research and development sectors if necessary;

(iv) Land availability for future expansion of palm oil plantations; and

(v) The challenges to enhance palm oil production and global distribution towards sustainability.

As for this research, the potential risks arising from the inherent limitations of the current supply network in the Malaysian palm oil industry were carried out. For example, with the current available data flow, any risks encountered by the plantation tier would affect the performance of the manufacturers therefore causing a negative impact on the product sustainability. In future, the potential risks identified can be useful to suppress the impacts arising under the supply network uncertainties where counter measures can be taken in order to maintain sustainability.

From the interview carried out, the responses from the officer in-charge confirmed that research studies conducted by SIRIM were focused mainly on environmental sustainability parameters which consist of:

i) Compliancy to the Environmental Management Systems;

Over the years, industrial activities which have led to environmental pollution have been gaining the attention of the Malaysian government. In order to show active involvement, the government has been promoting more environmentally friendly production by applying the Environmental Management Systems to mitigate the impacts from the pollution. In 1995, SIRIM launched the Environmental Management Systems certification scheme in line with ISO14001 in Malaysia. Protecting the environment from negative impact of industrial activities has become an important aspect that multi-nationals and export oriented companies have to portray to maintain their competitive edge in the international market.

ii) Product life cycle analysis from the environmental point of view; and

Since 2003, the SIRIM life cycle assessment team has been working on the application that is currently used to establish greenhouse gas profiles or carbon footprints aside from relating to impacts such as resource consumption, eutrophication (overly nutrient-rich water) and acidification.

iii) Eco-labelling.

Eco-label is a label which identifies overall environmental preference of a product or service within a specific product or service category based on life cycle considerations. In 1996, SIRIM launched the national eco-labelling program verifying products according to environmental criteria such as environmentally degradable, non-toxic plastic packaging material, hazardous metal-free electrical and electronic equipment, biodegradable cleaning agents and recycled paper.

The interview results were then translated using the interpretive structural modelling approach which has identified nine environmental sustainability parameters and their relationships. The findings from the analysed interactions of these parameters were used to explore potential impacts of the supply network design in the design of a sustainable industrial system.

1.2. ISO Standards

A range of standards have been developed in the last two decades to enable sustainable development (ISO 2006a). ISO 14000 standards create a systematic approach for reducing the impact on the environment due to the activities of an organization (ISO 14000). ISO 14000 standards include the ISO 14020 series for environmental labelling, ISO 14040 for Life Cycle Assessment, ISO 14064 for Green House Gases, as a few given examples. ISO 19011 provides guidelines for auditing quality and environmental management systems (ISO 19011). Figure 2 showed the examples of identified environmental sustainability drivers of life cycle stages which can be used for the proposed environmental sustainability reporting of the palm oil industry.

	Raw Material	Product Manufacturing	Transportation	Product Use	Product After Use
Environmental Sustainability Drivers					
1)Environmental Management	●	●	●		
2)Life Cycle Assessment	●	●	●	●	●
3)Green Labeling		●			
4)GHG Emissions		●	●		●
5)Climate Change	●				●
6)Energy Efficiency	●	●	●		
7)Renewable Resources	●				●
8)Water, Soil & Air Quality	●	●	●	●	●
9)Waste Management	●	●			●

Figure 2. Examples of identified environmental sustainability drivers of life cycle stages.

(i) Environmental Management
A number of palm oil mills and palm oil refineries in Malaysia have achieved certification to this ISO standard of environmental management. The standard requires organizations to assess their environmental impacts and develop an environmental policy to address them. The two specific requirements of relevance are:

- the policy includes a commitment to comply with relevant environmental legislation and regulations; and
- the policy includes a commitment to prevention of pollution.

Environmental management is an auditable standard that provides a framework for organizations to implement their environmental policies and can be verified by third party certification.

(ii) Life Cycle Assessment

In the ISO 14000 family of standards, the ISO 14040 standard provides the framework and guidance for conducting life cycle assessment (LCA). This is the "cradle-to-grave" approach for assessing the environmental profile and performance of a product from sourcing of raw materials to its final disposal after the useful life of the product. Application of this methodology to the palm oil industry would provide an assessment of the potential environmental impacts of all inputs and outputs throughout the production chain from the planting of the palm oil seed to the consumption of the final processed product.

(iii) Green Labelling

Green labelling refers to a scheme which awards green label to environmental friendly products. These are products that have less environmental impacts. The purpose of labelling these products is to help consumers to identify and purchase those products that are environmentally friendly. Strong demand from the consumers for environmental labelling products will encourage more manufacturers to adopt environmental friendly policies.

(iv) Greenhouse Gas Emissions

Carbon conservation aspects need to be addressed and greenhouse gas balance and land use competition should also be included in the design of sustainable industrial systems for the palm oil industry. Additional principles should be developed for palm oil sustainability, to cover aspects related to carbon balance and preservation of carbon stocks. As reducing greenhouse gas emissions is a prominent goal for sustainable development policies, certain levels of greenhouse gas reductions based on a life cycle assessment should be developed.

(v) Climate Change

Forest conversion by plantation companies contributes to climate change. Emission of carbon dioxide known as the greenhouse gas is a cause of global warming and climatic change. The rainforests which are cleared to make place for palm oil plantations are storing huge amounts of carbon. Massive amounts of carbon are released straight into the atmosphere but the land's ability to take up carbon dioxide is also diminished with these land conversions.

(vi) Energy Efficiency

Increasing energy efficiency will help to reduce the impact of energy consumption on climate change by replacing non-renewable energy with alternative renewable and low impact energy sources.

(vii) Renewable Resources

The efficient use of renewable resources should be targeted since the use of non-renewable resources, such as fossil fuel, is not sustainable in the long term. Greenhouse gases and polluting gaseous emissions must be minimised.

(viii) Water, Soil and Air Quality

During planting, several measures must be taken to prevent soil degradation and conserve soil fertility in order to minimise soil erosion and fertilizer loss. The soil is highly susceptible to erosion during the land preparation stage preceding planting palm oil trees are unique in a way that they have higher leaf area index that allows them to have better photosynthetic efficiency to produce more oxygen to the air and absorb more carbon dioxide from the atmosphere. Water quality around palm oil plantations and processing mills must be carefully handled to avoid from the impacts of using banned herbicides and pesticides for the use to control weeds and pests. Oily sludge of palm oil mill effluent from palm oil processing mills must be treated before being discharged into water systems to avoid water supply contamination.

(ix) Waste Management

All waste must be handled, stored and disposed off correctly to avoid pollution to minimize the amount of waste produced, thus reducing environmental cost and ensuring that legislative requirements are met.

2. Materials and methods

Interpretive structural modelling was first proposed by Warfield in 1973. Interpretive structural modelling referred henceforth as ISM, is aid for modelling relational structure among the number of parameters. While dealing with large number of attributes, it gets complicated to relate them with reference to the final goal. Interpretive structural modelling can help in interpreting the decision maker's judgment about relation among the parameters. It extracts a structured model out of pool of parameters to simplify decision making process.

The major steps involved in using interpretive structural modelling are as follows:

(i) Identification of parameters

The relevant parameters to be considered in final analysis are listed in Figure 2.

(ii) Structural self-interaction matrix

Depending on the situation and parameters, a contextual relation is chosen and compared with every other parameter to decide presence and direction of chosen relationship. This generates self interaction matrix.

(iii) Reachability matrix

From the self-interaction matrix, the relational indicators are converted in to binary digits 0 and 1 to get a square matrix, called reachability matrix. Simple transitivity check is done as, if parameter A relates to B and B relates C then A relates to C. This helps in extracting a consistent model from the set of parameters. Summations of row indicate driving power of the parameters and summations of column indicate dependence. Higher dependence rank and lower driver rank indicates dependent parameters, whereas lower dependence rank and higher driver rank indicate independent parameters. Lower dependence and driver rank indicate autonomous parameter, whereas higher dependence and driver rank indicate linked parameters.

(iv) Level partition

From reachability matrix, for each parameter, reachability set and antecedent sets are derived. Reachability set contains parameter itself and other parameters to which it may reach. Antecedent set contains parameter itself and other parameters which may reach to it. Depending on intersection of these sets, the parameters are partitioned in hierarchical levels.

(v) Construction of interpretive structural modeling

From the partitioned set of parameters and reachability matrix, structured model is derived, indicating parameters in each level and arrows indicating direction of relationship present. Such a graphic representation of model is called diagraph.

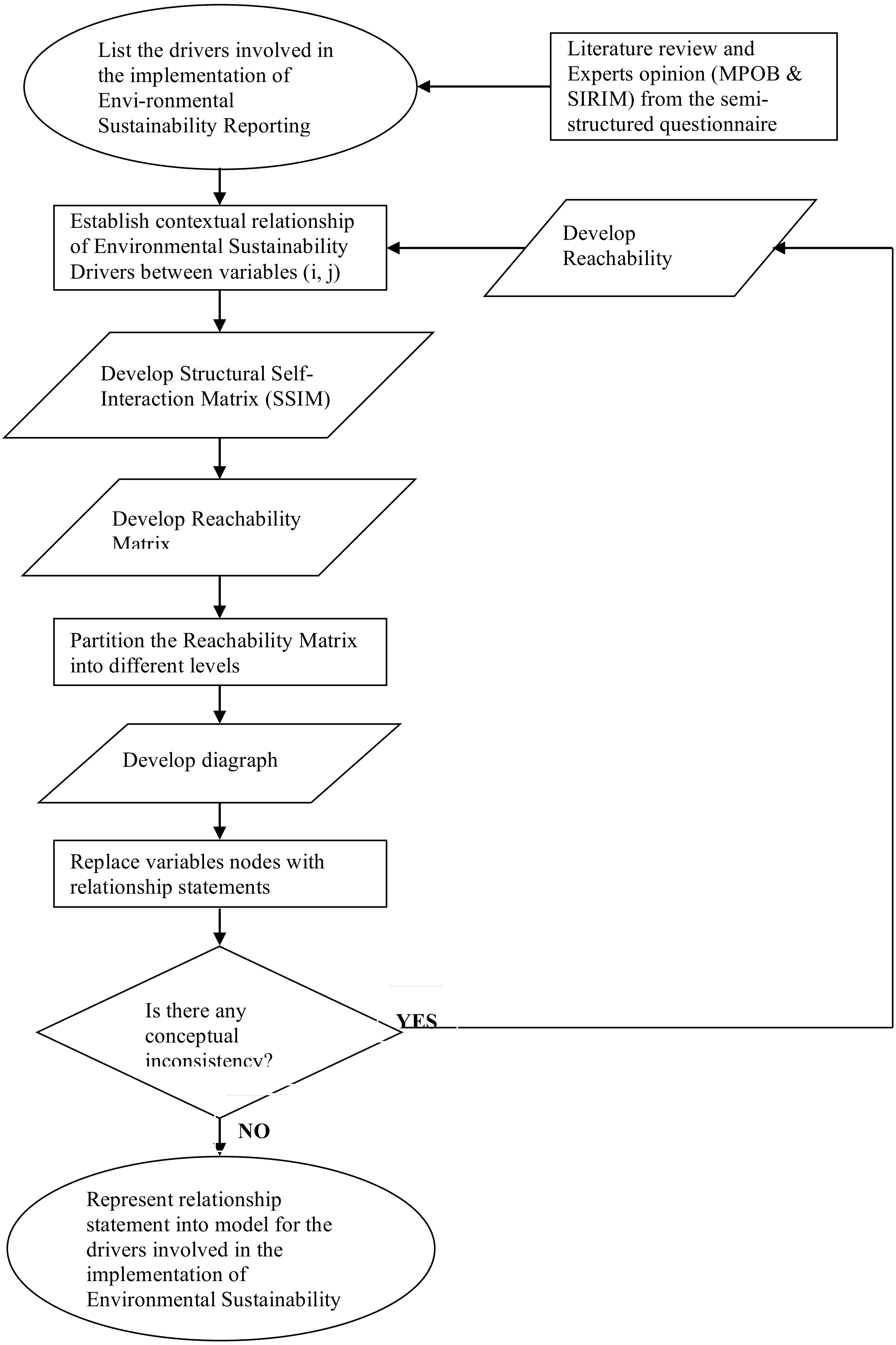

Figure 3. Flowchart of interpretive structural modeling methodology.

In this paper, the examples of contextual relationship between parameters in environmental sustainability were analysed using the interpretive structure modelling. The first step of using interpretive structural modelling was to analyse the contextual relationship of type “leads to”. That is one environmental sustainability (ES) parameter leads to another parameter. Based on this contextual relationship, a structural self-interaction matrix was developed. The various steps involved in interpretive structural modelling methodology are shown in the flowchart in Figure 3 (Kannan, Pokharel & Sasikumar 2009).

3. Results and discussion

3.1. Structural self-interaction matrix

The first step is to analyze the contextual relationship of type “leads to”. That is one Environmental Sustainability leads to another. Based on this contextual relationship, a structural self-interaction matrix is developed. In this research, 3 experts, from the research based industries were consulted in identifying the nature of contextual relationship among the environmental sustainability drivers.

Water, soil and air quality (without pollution) determine agricultural sustainability (Acton & Gregorich 1995; Papendick & Parr 1992) and environmental quality (Pierzynski, Sims & Vance 1994) and have impacts on environmental pollution, degradation and depletion of natural and non-renewable resources (Power 1996). Applying renewable resources will minimise pollution and by using green labelling and life cycle assessment will help to provide qualitative and quantitative information regarding consumption of material. Energy use is a major source of emissions, thus achieving energy efficiency is important to control greenhouse gas emissions, assessing life cycle and managing the environment. Concerns about degradation of natural resources and climate change have triggered the need for preventive measures of environmental protection. Promotion of renewable resources and green labelling will be achieved by implementing life cycle assessment and environmental management systems. These will help to reduce the greenhouse effect. The development of an Environmental Management System (EMS) includes rational land use planning, water management, energy management (promotion of renewable energy sources, promotion of clean and energy efficient technologies), waste management (minimization, recovery, reuse, recycle, etc.) and life cycle assessment. Waste management is regarded to re-use, recycle, repair, life extension, incineration (with or without energy recovery), landfill and composting and is unrelated to climate change and GHG emissions. Water, soil and air quality are referred to unpolluted and emissions which can lead to erosion, climate change and ozone depletion. They are not related to energy efficiency and green labelling. Renewable resources are non-depletable resources which can be used in a cleaner and more efficient technologies manner and non-related to GHG emissions. Energy efficiency and climate change are not related to green labelling.

Following, four symbols are used to denote the direction of relationship between the Environmental Sustainability Drivers (i and j):

V: ES i will help to achieve ES j		
Environmental Sustainability of i	will help to achieve	Environmental Sustainability of j
Water, Soil and Air Quality		Climate Change
Renewable Resources		Green Labelling Life Cycle Assessment
Energy Efficiency		GHG Emissions Life Cycle Assessment Environmental Management
A: ES j will be achieved by ES i		
Environmental Sustainability of j	will be achieved	Environmental Sustainability of i
Renewable Resources		Climate Change
Climate Change		Life Cycle Assessment Environmental Management
Green Labelling		Environmental Management
X: ES i and j will help to achieve each other		
Environmental Sustainability of i	will help to achieve each other	Environmental Sustainability of j
Waste Management		Water, Soil and Air Quality Renewable Resources Energy Efficiency Green Labelling Life Cycle Assessment Environmental Management
Water, Soil and Air Quality		Renewable Resources GHG Emissions Life Cycle Assessment Environmental Management
Renewable Resources		Energy Efficiency Environmental Management
Energy Efficiency		Climate Change
Climate Change		GHG Emissions
GHG Emissions		Green Labelling Life Cycle Assessment Environmental Management
Green Labelling		Life Cycle Assessment
Life Cycle Assessment		Environmental Management
O: ES's i and j are unrelated		
Environmental Sustainability of i	unrelated to	Environmental Sustainability of j
Waste Management		Climate Change GHG Emissions
Water, Soil and Air Quality		Energy Efficiency Green Labelling
Renewable Resources		GHG Emissions
Energy Efficiency		Green Labelling

Climate Change		Green Labelling

Based on expert's responses, the structural self-interaction matrix is constructed as shown in Table 1.

3.2. Reachability matrix

The structural self-interaction matrix for environmental sustainability is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1s and 0s are as follows:

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Then its transitivity is checked (which means if Environmental Sustainability of i leads to Environmental Sustainability of j and Environmental Sustainability of j leads to Environmental Sustainability of i, then Environmental Sustainability of i should lead to Environmental Sustainability of j) and the final reachability matrix as shown in Table 2 is obtained. In this table, the driving power and dependence of each Environmental Sustainability's are also shown. The driving power of a particular Environmental Sustainability is the total number of Environmental Sustainability (including itself) which it may help to achieve. The dependence is the total number of Environmental Sustainability which may help achieving it.

Table 1. Structural self-interaction matrix for Environmental Sustainability.

Environmental Sustainability	9	8	7	6	5	4	3	2	1
1.Environmental Management	**X**	**X**	**X**	**V**	**A**	**X**	**A**	**X**	-
2.Life Cycle Assessment	**X**	**X**	**V**	**V**	**A**	**X**	**X**	-	
3.Green Labeling	**X**	**O**	**V**	**O**	**O**	**X**	-		
4.GHG Emissions	**O**	**X**	**O**	**V**	**X**	-			
5.Climate Change	**O**	**V**	**A**	**X**	-				
6.Energy Efficiency	**X**	**O**	**X**	-					
7.Renewable Resources	**X**	**X**	-						
8.Water, Soil and Air Quality	**X**	-							
9.Waste Management	-								

Table 2. Final reachability matrix.

Environmental Sustainability Drivers	1	2	3	4	5	6	7	8	9	Driving Power
1.Environmental Management	1	1	0	1	0	1	1	1	1	7
2.Life Cycle Assessment	1	1	1	1	0	1	1	1	1	8
3.Green Labeling	1	1	1	1	0	0	1	0	1	6
4.GHG Emissions	1	1	1	1	1	1	0	1	0	7
5.Climate Change	1	1	0	1	1	1	0	1	0	6
6.Energy Efficiency	0	0	0	0	1	1	1	0	1	4
7.Renewable Resources	1	0	0	0	1	1	1	1	1	6
8.Water, Soil and Air Quality	1	1	0	1	0	0	1	1	1	6
9.Waste Management	1	1	1	0	0	1	1	1	1	7
Dependence Power	8	7	4	6	4	7	7	7	7	

3.3. Level partitions

From the final reachability matrix, the reachability set and antecedent set for each ES is found. The reachability set includes Environmental Sustainability itself and others which it may help to achieve, similarly the antecedent set consists of Environmental Sustainability itself and the other Environmental Sustainability's which help in achieving it. Then, the intersection of these sets is derived for all Environmental Sustainability's. The Environmental Sustainability for which the reachability and intersection sets are same is the top-level Environmental Sustainability in the interpretive structural modeling hierarchy.

Table 3. Iteration i.

Environmental Sustainability Drivers	Reachability Set	Antecedent Set	Intersection Set	Level
1.Environmental Management	1,2,4,6,7,8,9	1,2,3,4,5,7,8,9	1,2,4,7,8,9	**I**
2.Life Cycle Assessment	1,2,3,4,6,7,8,9	1,2,3,4,5,8,9	1,2,3,4,8,9	
3.Green Labeling	1,2,3,4,7,9	2,3,4,9	2,3,4,9	
4.GHG Emissions	1,2,3,4,5,6,8	1,2,3,4,5,8	2,3,4,5,8	
5.Climate Change	1,2,4,5,6,8	4,5,6,7	4,5,6	
6.Energy Efficiency	5,6,7,9	1,2,4,5,6,7,9	5,6,7,9	
7.Renewable Resources	5,6,7,8,9	1,2,3,6,7,8,9	6,7,8,9	
8.Water, Soil and Air Quality	1,2,4,7,8,9	1,2,4,5,7,8,9	1,2,4,7,8,9	**I**
9.Waste Management	1,2,3,6,7,8,9	1,2,3,6,7,8,9	1,2,3,6,7,8,9	

The top-level Environmental Sustainability in the hierarchy would not help achieve any other Environmental Sustainability above its own level. Once the top-level ES is identified, it is separated out from the other Environmental Sustainability's (Table 3). Then, the same process is repeated to find out the Environmental Sustainability's in the next level. This process is continued until the level of each Environmental Sustainability is found. Results for the iteration process are summarized in Table 4. The resulting levels help in building the digraph and the final model.

Table 4. Iteration ii-v.

Iteration	ES's	Reachability Set	Antecedent Set	Intersection Set	Level
ii	2	2,3,4,6,7,9	2,3,4,5,9	2,3,4,9	**II**
ii	3	2,3,4,7,9	2,3,4,9	2,3,4,9	**II**
iii	7	5,6,7,9	6,7,9	6,7,9	**III**
iii	9	6,7,9	6,7,9	6,7,9	**III**
iv	4	4,5,6	4,5	4,5	**IV**
iv	5	4,5,6	4,5,6	4,5	**IV**
v	6	6	6	6	**V**

3.4. Building the ISM model

From the final reachability matrix (Table 2), the structural model is generated. If there is a relationship between the Environmental Sustainability's i and j, this is shown by an arrow which points from i to j. This graph is called a directed graph, or digraph. After removing the transitivity's the digraph is finally converted into the interpretive structural modeling-based model (Figure 4).

Several interesting findings for the implementation of environmental sustainability arise from the application of interpretive structural modelling approach. The findings offered new considerations regarding the successful implementation of sustainability reporting. In this analysis, the dependence power and driver power of the variables are analyzed. On the basis of the above study, the drivers were classified into four sectors. The four sectors are autonomous, dependent, linkage, and driver/independent (refer to Figure 5). In the final reachability matrix, shown in Table 3, the driving power and dependence of each of the drivers are calculated. The drivers that have weak driver power and weak dependence will fall in Sector I and are called autonomous drivers. Drivers that have weak driver power, but strong dependence power will fall in Sector II and are called dependent drivers. Drivers that have both strong driver power and dependence power will fall in Sector III and are called linkage drivers. These drivers are unstable due to the fact that any action on these drivers will affect the others, and may also have a feedback effects on themselves. Drivers that have strong driver power but weak dependence power will fall in Sector IV and are called independent drivers (Kannan & Haq 2007).

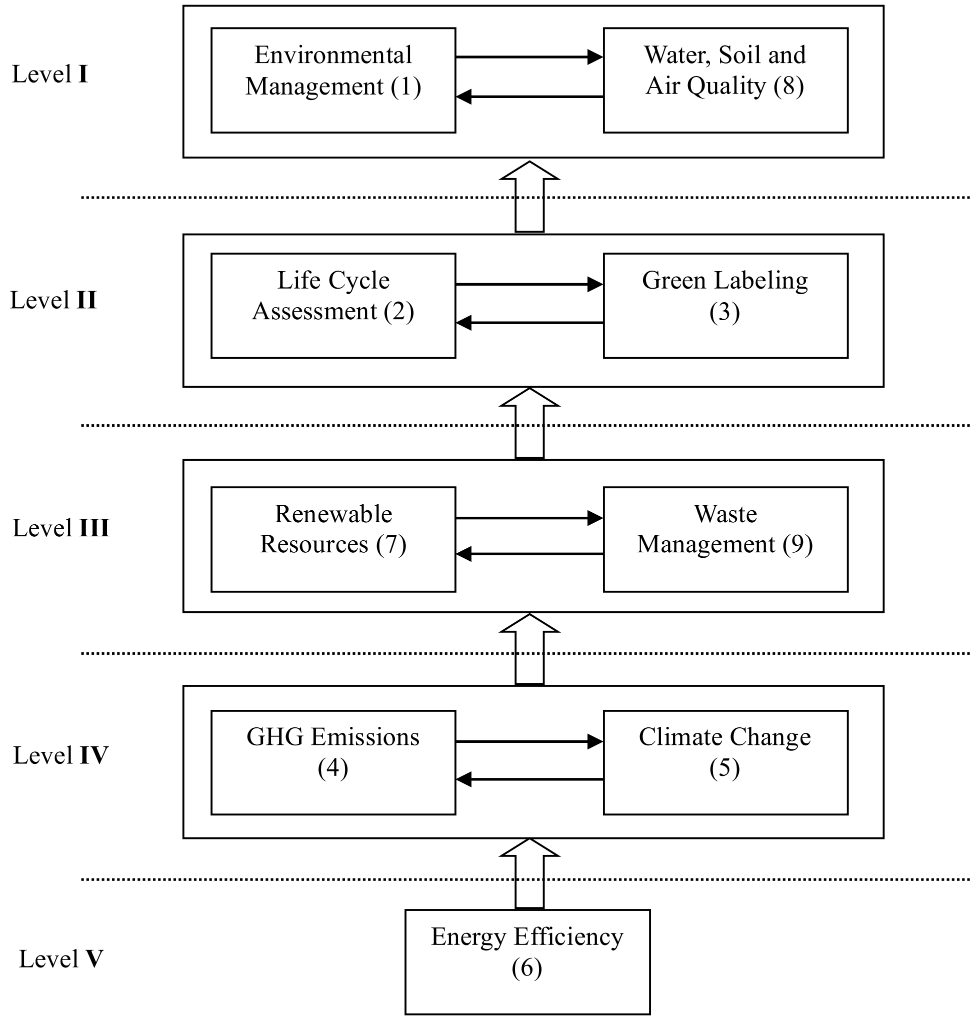

Figure 4. Structural model of Environmental Sustainability Drivers.

From the structural model of environmental sustainability generated, it showed that ISO14001 (Environmental Management Systems) and ISO14040 (Life Cycle Assessment) were at the top and second level. This model has concluded that the significance of these tools application as part of a useful guideline to aid decision making in sustainability reporting based on the analysed parameters and evaluation of environmental sustainability criteria. The drivers involved in the environmental sustainability reporting for Malaysian palm oil industry case study pose considerable challenges. Decision makers must be aware of the relative importance of the various drivers and the techniques for implementing them. Highlighting the 9 types of drivers, an interpretive structural modelling-based model was developed and the interactions between these drivers were analyzed. From Figure 4, it is evident that energy efficiency is the significant driver to reduce and eliminate product environmental impact, which is in tern critical to achieving the sustainability certification between suppliers in the supply chain network. Life cycle assessment, green labelling, renewable resources, waste management, GHG emissions and climate change are placed at an intermediate level of the interpretive structural modelling-based model. Environmental management and water, soil and air quality are at the top level of the interpretive structural modelling-based model hierarchy.

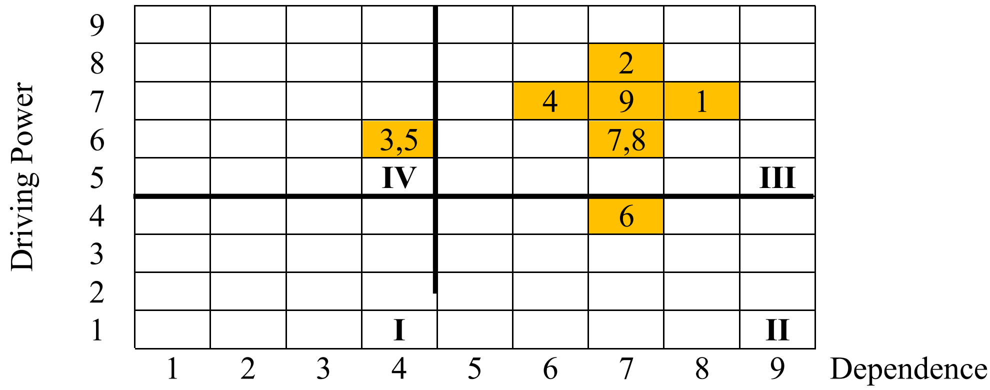

Figure 5. Driving power and dependence diagram.

Sector **I**: Autonomous Driver
Sector **II**: Dependent Driver
Sector **III**: Linkage Driver
Sector **IV**: Independent Driver

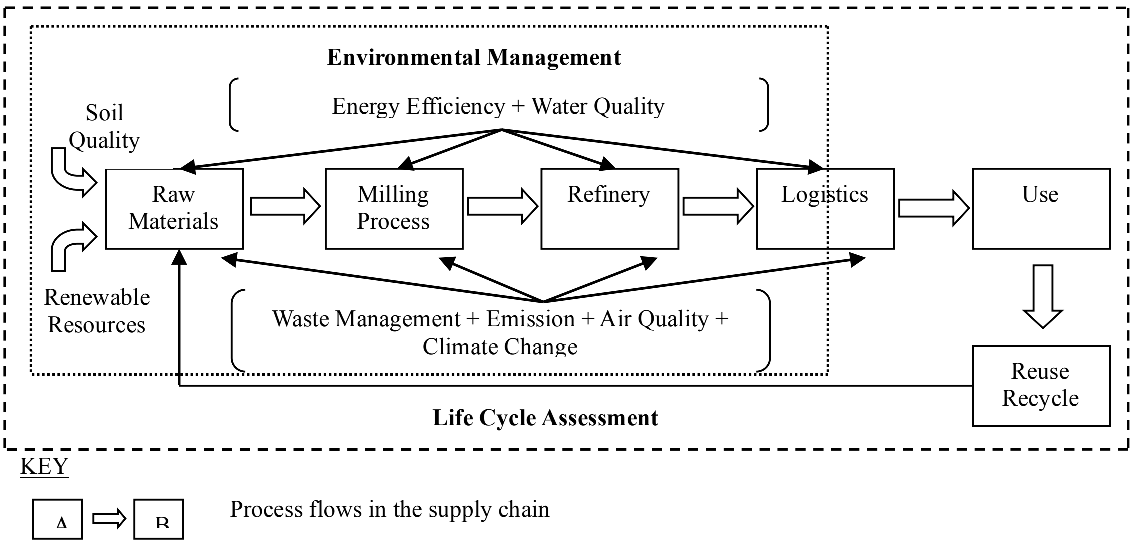

Figure 6. Environmental sustainability reporting drivers in the Malaysian palm oil industry.

3.4. Predicting the palm oil products life cycle to improve sustainability reporting

From the driving power and dependence diagram shown in Figure 5, it is evident that there is no driver that has weak dependence and weak driving power, so there are no drivers that map to Sector I. Next, the energy efficiency driver is found to have weak driving power and strong dependence power so it maps to Sector II. In this case, implementation of environmental management, life cycle analysis, GHG emissions, renewable resources, water, soil and air quality and waste management are found to have strong driving power and strong dependence power so they map to Sector III. These drivers are unstable due to the fact that any change occurring to them will affect other drivers and may be affected through a feedback mechanism (Qureshi, Kumar D & Kumar P 2008). Lastly, the green labelling and climate change drivers possess strong driving power and weak dependence power so they map to Sector IV. The above model is based on the interpretive structural modelling methodology, which has its own limitations. For example there will be subjective bias of the person who is judging the drivers, as the relations among the drivers always depends on that person's knowledge and familiarity with the industry.

Table 5. Examples of environmental sustainability drivers' indicators and units of life cycle stages of the Malaysian palm oil industry.

Environmental Sustainability Drivers	**Indicators**	**Units**
1) Environmental Management	Compliancy to the Environmental Management Standards	Number or %
2) Life Cycle Assessment	A specific entire product life cycle from the environmental point of view	Number or %
3) Green Labeling	Labels on products indicating carbon footprints, water and energy use, resource consumption and health impacts	Number or %
4) GHG Emissions	Emissions in total	CO_2 equivalent kg/yr or t/yr
5) Climate Change	Contribution to global warming	CO_2 equivalent
6) Energy Efficiency	Energy used in total	TJ/yr
7) Renewable Resources	Rate of renewable resources (relative to total world/regional reserves)	%
8) Water, Soil and Air Quality		
For water	Amount of water used	m^3/yr
For soil	Amount of soil used	ha/yr
For air	Amount of air pollutions	kg/yr or t/yr
9) Waste Management	Amount of solid waste (hazardous or non-hazardous)	kg/yr or t/yr

Issues of product sustainability are being undertaken in supply chain network by using simulation analysis and subsequently to ascertain a novel approach to outline a guideline of their product life cycle. It is intended that the standard of environmental sustainability reporting can utilize these drivers (shown in Figure 6) as part of a useful guideline to aid decision making. The novelty of this research is that it identifies the significance of environmental sustainability reporting based on the analyzed drivers and provides evaluation of environmental sustainability criteria's. This paper has provided a structural model of environmental sustainability and its associated method was developed by using the interpretive structural modelling model to determine the potential drivers in environmental sustainability reporting. The developed model can be used in the design life cycle of a product whether it is viable to be reused, remanufactured or recycled and subsequently to improve its sustainability. Indicators and units examples of the environmental sustainability indicators and units of life cycle stages related to the Malaysian palm oil industry were shown in Table 5.

4. Conclusion

In order to achieve sustainable products, an interpretive structural modelling approach was conducted to better understand the drivers related to environmental sustainability reporting in the supply network chain related to the Malaysian palm oil industry. This paper has identified nine (9) environmental sustainability drivers and the relationships between them. The findings from the environmental sustainability reporting drivers of this study can be furthered use to explore the potential impacts of supply chain network design on sustainability using the Malaysian palm oil industry as a reference.

The decision makers related to the Malaysian palm oil industry will be directly benefited from the outcome of this research, as this would help them in prioritizing decision-making efforts on various issues. The interpretive structural modelling is a useful tool for decision makers to differentiate between independent and dependent drivers and their mutual relationships. This would help them to focus on the identified key parameters that are important for effective implementation towards the definition of sustainability in the Malaysian palm oil industry. The strongest driver in the decision-making process of this industry is energy efficiency. By increasing energy efficiency will help to reduce the impact of energy consumption on climate change. This is perhaps the reason why issue relating to energy efficiency is in the level of the strongest driver. This issue has triggered the next level of issues, which includes greenhouse gas emissions and climate change. As climate change is primarily affected by the greenhouse gas emissions, replacing non-renewable energy with alternative renewable and low impact energy sources can help to increase energy efficiency. The next level of issues as shown in the interpretive structural modelling-based model in Figure 4 covers the issues related to renewable resources and waste management. This level of issues is primarily at the cradle-to-grave life cycle, where efficient use of renewable resources and successful implementation of waste management will ensure long term sustainability achievement. In the next level of issues, life cycle assessment and green labelling are applicable to provide an assessment of the potential environmental impacts of all inputs and outputs throughout the production chain and to produce environmental friendly products. The final issues are the environmental management and water, soil and air quality which are important to access environmental impacts and to prevent contamination.

The importance of having clear information requirements based on the different impacts in the supply network tiers can be used to capture data related triple bottom line performance indicators in the design of sustainable industrial systems (Choong & Alison 2013). As an example, green labelling for carbon footprint is part of the control measures taken to reduce environmental impact of products and services throughout the life cycle of the Malaysian palm oil industry supply network. As for further research, simulation analysis can be carried out to determine the influence effect of these drivers had on the performance of the network. From the performance analysis, focus can be better made on the sensitivity of triple bottom line to factors of uncertainties of the supply chain network in order to understand the potential risks of sustainability in palm oil supply chain network and could be diagnosed for better sustainability development indicators.

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