Sustainable Supply Chain Performance Measurement A Case Study of the Sugar Industry

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Abstract

The purpose of this paper is to introduce a framework to measure the sustainable performance of supply chains. The supply chain stakeholders in this study are suppliers, a manufacturer, customer and the surrounding community. The proposed sustainable supply chain performance measurement consists of three dimensions with 14 indicators. In order to assess overall sustainability of the studied supply chain, a composite index is developed to combine all indicators to reflect the sustainability performance of the supply chain. The case of the sugar industry in Thailand is selected as an illustrative case. There are 4 steps to create the composite index which are (1) measuring value (2) normalization method (3) weighting of indicators (4) aggregation method. The numerical example, based on obtained data of the Thai sugar industry, is provided in order to explain how to calculate the composite index. The findings show that the overall sustainable supply chain score of the manufacturer is 55.61% while suppliers, customers and the community, achieved a composite index score of 80.97% and 75.00% respectively. The major contribution of this paper is the development of sustainable supply chain indicators between supply chain stakeholders and an approach to measure overall sustainable supply chain performance via the development of a composite index.

Keywords
Sustainable, Supply Chain, Performance Measurement, Sugar Industry, Numerical Example

1. Introduction

Sustainability is an important performance dimension that needs to be considered when designing supply chains. Sustainable Supply Chain (SSC) is driven by environmental and social objectives with economic benefits (Taticchi, et al., 2013). A sustainable supply chain will therefore theoretically enable competitiveness of all supply chain members. In order to enhance the competitiveness of supply chains it is important to first assess supply chain performance. Several researchers have proposed frameworks for sustainable performance with quantitative indicators (e.g. Azapagic and Perdan, 2000; Krajnc and Glavic, 2003; Tan, et al., 2015). These proposed indicators emphasized effectiveness and efficiency in terms of performance. Efficiency is used to measure input utilization while effectiveness is used to measure goals or outputs of organizations. These effectiveness and efficiency

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indicators need to also be able to to measure the value added along any given supply chain. The purpose of this paper is to propose a more holistic framework to help measure supply chains sustainable performance.

2. Sustainable Supply Chain Performance Indicators

Currently, indicators related to sustainable supply chain performance are numerous and difficult to select for generic performance evaluation. The Global Reporting Initiative (GRI), which was defined by the United Nations Environment Programme: UNEP in 1997, provides a standard framework for sustainable performance. GRI is the most widely used standard for sustainability reporting that can be used for all organizations irrespective of their size, sector or location. The main domain of the GRI focuses on economic, environment and social dimensions. The GRI guideline offers more than two hundred indicators that may be selected to evaluate each organizations. Apart from following the GRI framework, other researchers such Seuring and Müller in 2008 or Hassini, et al., in 2012 have also proposed their respective sustainability framework for consideration. The main challenge is that the GRI indicators have not been developed to evaluate supply chains. The GRI indicators are more suitable to measure the sustainability performance of individual supply chain members and not the supply chain as a whole. Table 1 shows the reviewed literature on indicators of sustainable supply chain performance based on the three dimensions, as describes below;

2.1. The Economic Dimension

The economic dimension is a key dimension in the evaluation of performance. These economic indicators aim to assess organizational capability. The most common economic indicators are: profitability, costs, flexibility, timeless, productivity, quality and employment (Gunasekaran, et al., 2004). Economic indicators can be categorized into financial and non-financial indicators. Profitability and costs are financial measurement. Profitability can assess business performance. Profitability can be measured with indicators such as return on investment (ROI), return on assets (ROA) and net profit. Actual cost can also be used to evaluate supply chain performance. In addition, cost indicators can focus on micro-level activities such as manufacturing cost, operation cost, transport cost, inventory cost, labour cost and logistics cost. In order to evaluate non-financial issues indicators such as timeliness, flexibility, productivity, quality and employment can be considered. Flexibility is related to manufacturing flexibility at all stages of the supply chain. Flexibility is focused on delivery time that affects customer decision to place orders. To measure flexibility, Gunasekaran (2004) proposed production delivery cycle time, machine or tool set up time and inventory turnover. Within the supply chain there is a need to enable more flexibility through volume and delivery flexibility. These two indicators measure the ability to respond to demand and delivery variance. Timeliness can be used to measure on-time delivery of suppliers to reflect their reliability capability. Timeliness of delivery can be applied when assessing delivery speed and reliability. Moreover, inventory turnover rate is another key indicator that can measure timeliness of operational performance (Yeung, 2008). Productivity is the comparison of input and output within industry. It can be measured by the ratio of a worker time on productive activities and the total time available for productive work. Quality is a non-financial indicator that can measure economics performance as it refers to zero waste of production along the supply chain. Employment indicators can be a reflection of long-term development (Tan, et al., 2015).

2.2. The Environmental Dimension

Firms need to consider their respective environmental impact by making their operations more environmentally friendly. The environmental dimension is composed of resource consumption, energy consumption, and emissions and wastes (GRI, G4). Resource usage needs to be measured in machines, materials, water, air, soil and land. Efficiency usage of resources can save costs and energy in manufacturing and other supply chain activities. Bouchery, et al. (2010) discussed energy use and GHG emission KPIs for transportation and warehouse activities. Resource consumption is one criteria used in the environmental dimension. Energy usage can assess environmental performance by assessing energy consumption and fuel efficiency (Gupta and Kumar, 2013). Renewable energy sources are important issue for sustainability. Emissions and wastes include air emission, CO_2 emission, waste water generation, solid waste disposal, and consumptions of hazardous/harmful/toxic materials. Vinodh, et al. (2011) presented environmental performance metrics that are non-product output measures. There exist environmental issues such as air emission, water pollution and solid waste that are derived from supply chain activities.

Table 1. Indicators of Sustainable Supply Chain

Sources	Sustainable Perspectives																																							
	Economic																			**Environment**										**Social**										
	Return of Investments (ROI)	Return of Assets (ROA)	Net Profit	Manufacturing Cost	Cost per Operating Hour	Transport Cost	Inventory Cost	Labor Cost	Logistics Cost	Volume Flexibility	Delivery Flexibility	Production Delivery Cycle Time	Machine/tool Set Up Time	On-time Delivery Percentage	Manufacturing Lead Time	Inventory Turnover	Productivity	Quality of Products	Employment Rate	Energy Use per Product Unit	Renewable Energy Usage	Resource Use per Product Unit	Resource Utilization	Space Use	Waste Minimization	Air Emission Generated	Water Pollution	Solid Waste	GHG Emission	Work-related Injuries and Illnesses Rate	Work Condition: Absenteeism	Noise Pollution	Employee Turnover	Employee Training Expenses	Percentage of Employee Training	Labor Productivity Rate	Knowledge Sharing	Net Availability of Employees	Customer Complaints	Customer Response Time
Gunasekaran, et al., 2004	x	x										x	x			x																							x	
Lohman, et al., 2004										x	x																												x	
Soosay and Cahpman, 2006;								x						x		x																								
Bhagwat and Sharma, 2007				x	x		x																																	
Forberg and Saukkoriipi, 2007																	x		x											x						x				
Gaiardelli, et al., 2007	x	x								x	x																												x	
Markley and Davis, 2007	x	x																																					x	
Yeung, 2008	x	x		x										x	x	x																							x	
Chen, et al., 2009																																					x		x	
Erol , et al., 2009;																				x	x	x		x	x				x			x						x	x	
Schmidberger, et al., 2009								x	x																													x		
Bouchery, et al., 2010						x								x						x		x		x					x	x	x									
Dossi and Patelli, 2010																																	x	x		x				

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	Return of Investments (ROI)	Return of Assets (ROA)	Net Profit	Manufacturing Cost	Cost per Operating Hour	Transport Cost	Inventory Cost	Labor Cost	Logistics Cost	Volume Flexibility	Delivery Flexibility	Production Delivery Cycle Time	Machine/tool Set Up Time	On-time Delivery Percentage	Manufacturing Lead Time	Inventory Turnover	Productivity	Quality of Products	Employment Rate	Energy Use per Product Unit	Renewable Energy Usage	Resource Use per Product Unit	Resource Utilization	Space Use	Waste Minimization	Air Emission Generated	Water Pollution	Solid Waste	GHG Emission	Work-related Injuries and Illnesses Rate	Work Condition: Absenteeism	Noise Pollution	Employee Turnover	Employee Training Expenses	Percentage of Employee Training	Labor Productivity Rate	Knowledge Sharing	Net Availability of Employees	Customer Complaints	Customer Response Time
Yee, et al., 2010	x	x																																					x	
Adel El-Baz, 2011;				x						x	x																												x	x
Dey, et al., 2011									x																															
Gheewala, et al., 2011;			x																																					
Vinodh, et al., 2011																				x		x			x	x	x	x												
Gopalakrishnan, et al., 2012;																														x					x					
Grigoroudis, et al., 2012			x													x																			x				x	
Govindan, et al., 2013				x																					x														x	

Source: Authors

Indicators for environmental dimension can be assessed with energy consumption, resource consumption as well as emission and waste (EPA, 2007).

2.3. The Social Dimension

The social dimension assesses supply chain members (e.g. communities, employees and customers) within four main indicators. These are customer satisfaction, employee satisfaction, noise pollution, health and safety (Gunasekaran, et al., 2004; Lohman, et al., 2004; Soosay and Cahpman, 2006; Forberg and Saukkoriipi, 2007; Gaiardelli, et al., 2007; Markley and Davis, 2007; Yeung, 2008; Chen, et al., 2009; Bouchery, et al., 2010; Yee, et al., 2010; Adel El-Baz, 2011; Gopalakrishnan, et al., 2012; Grigoroudis, et al., 2012Govindan, et al., 2013). Customer satisfaction is an output measure. Customer complaint is a metric used to measure customer satisfaction. Customer response time or order cycle time measures the amount of time between an order and its corresponding delivery. Moreover, employee satisfaction is within the domain of human resource management that impacts business activities. The role of human resource is to assess human performance by human capabilities, labour productivity (Freeman, 2008).

Dossi and Patelli (2010) proposed people related indicators such as employee turnover, employee training expenses, labor productivity. Additionally, Schmidberger, et al. (2009) presented net availability of employees to measure performance. Noise pollution has a social impact that affects health and safety of employees and the surrounding community. Erol, et al. (2009) proposed sustainable metric for noise pollution. The identified key indicators in the performance of the social dimension are customer satisfaction, employee satisfaction, noise pollution as well as health and safety. These indicators can be used to measure the social dimension of individual supply chain members.

Based on the existing reviewed literature, sustainable supply chain performance measurement can be based on three dimension with a total of 14 indentified key indicators, as shown in Figure 1. The proposed key indicators are (1) profitability, (2) costs, (3) flexibility, (4) timeliness, (5) productivity, (6) quality, (7) employment, (8) energy consumption, (9) resource consumption, (10) emission and waste, (11) employee satisfaction, (12) customer satisfaction, (13) health and safety, (14) noise pollution. These indicators can be used to assess the sustainable performance of supply chains.

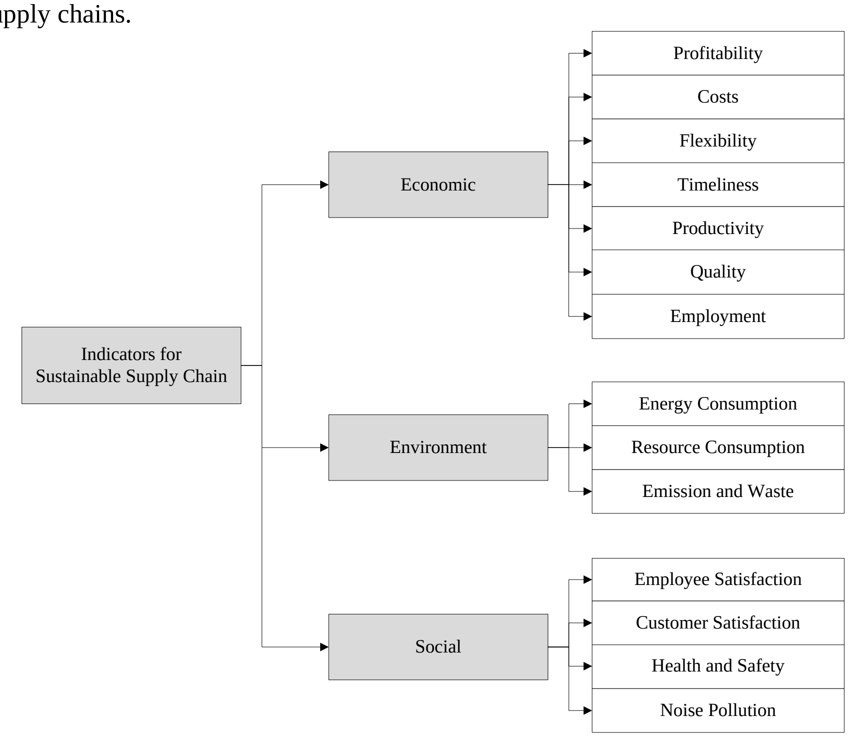

Figure 1. Indicators of Sustainable Supply Chain Performance Measurement

Supply chain stakeholders have an important role to play in the development of sustainable supply chain operations. The stakeholders in any given supply chain are suppliers, employees, the community and of course customers. Figure 2 describes the proposed sustainable indicators framework for all supply chain stakeholders.

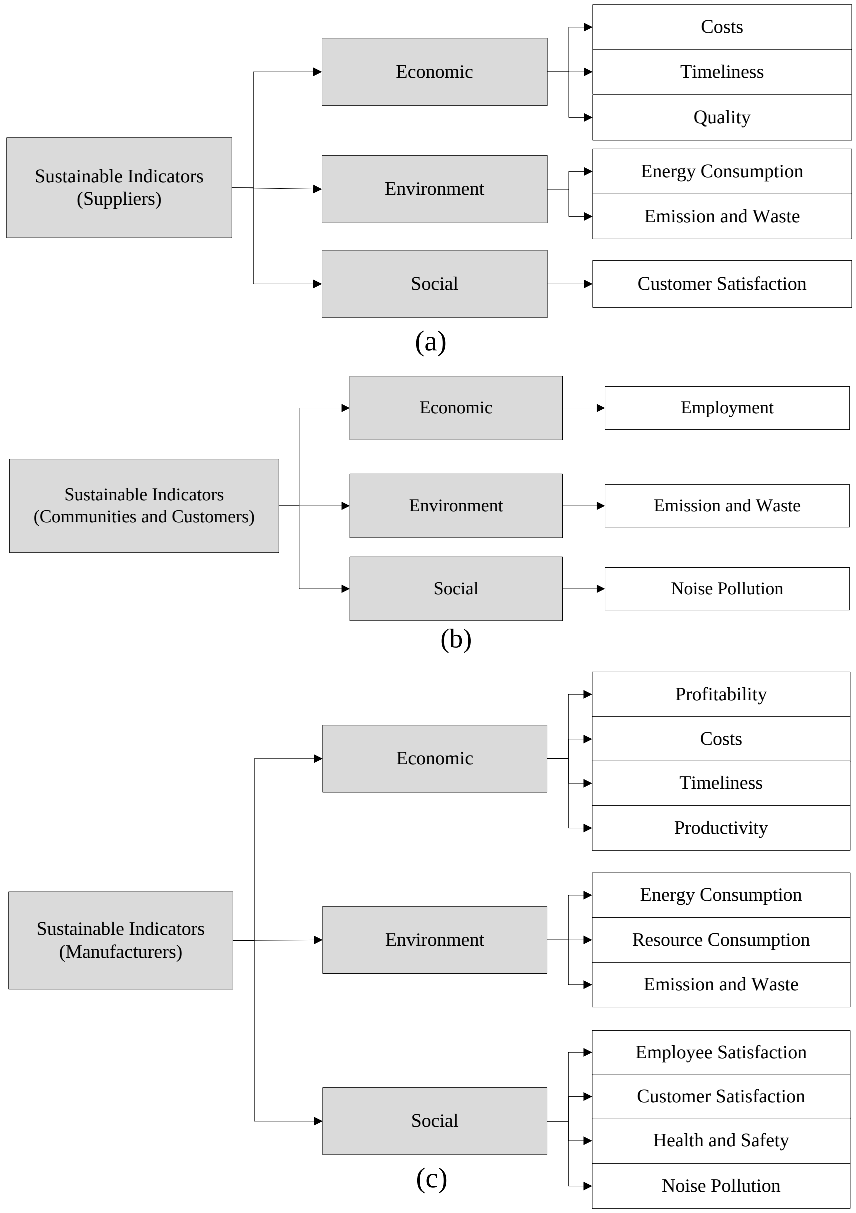

Figure 2. Sustainable Indicators through Stakeholders
(a) Suppliers (b) Communities and Customers (c) Manufacturers

Suppliers mostly focus on cost and reliability as they are very concerned with the in-full and on-time delivery of their supplies to manufacturers. For the delivery of their goods, suppliers also need to consider energy usage and air emission at the same time. For manufacturers, the measurements are used to evaluate economics, environmental and social dimensions. Economic dimension includes profitability, cost, on-time delivery and productivity. There are four indicators for the environmental dimension comprising of energy consumptions, resource consumptions, air emission and waste minimization. Also, the social dimension focuses on employee to measure employee satisfaction, health and safety including customer satisfaction. Working condition is an important factor for employees in terms of health and safety. Customer satisfaction is used measure number of complaints from the manufacturing side. Moreover, the measurements, which concern customers and communities, will focus on environmental and social impacts. There are three indicators that measures social and environmental dimension: employment rate, air emission and noise pollution.

3. A Numerical Example: The Thai Sugar Supply Chain

A numerical example is presented to illustrate application of the proposed supply chain sustainable performance framework. The context of this example is the Thai sugar industry. In order to measure the overall sustainability of the supply chain, a composite index can be developed to reflect the overall assessment. A composite index is widely used for combination of individual indicators (Singh, et al., 2007; Singh, et al., 2009). This composite index will represent the overall sustainable supply chain performance that encompasses all discussed different performance dimensions.

There are four steps to create a composite index that will measure overall sustainable supply chain performance. The indicators are first calculated to measure actual value. Secondly, a normalization method is used to convert different units of measurement into a standard measurement. To define standard measurements, the literature review has provided levels of measurements as shown Table 2. There are five scales, with 5 being the maximum value and 1 is minimum value. The proposed measurements are only valid for sugar manufacturing and need to be further normalized for comparison purposes.

Table 2. Levels of Measurements

Indicators	Levels of Measurements				
	1	2	3	4	5
Net Profit	<5%	5-10%	11-15%	15-20%	>20%
Manufacturing Cost	>75%	70-75%	60-69%	50-59%	<50%
On-time Delivery (O'Byrne, Key Performance Indicators for Supply Chain and Logistics)	<90%	90-95%	95-97%	97-99%	100%
Productivity	0-39%	40-59%	60-79%	80-89%	90-100%
Resource Use (Yakovieva, et al., 2009)	>80%	64-79%	48-63%	32-47%	<32%
Air Emission (European Union Energy Label)	<54%	55-68%	69-80%	81-91%	92-100%
Waste Minimization	81-100%	61-80%	41-60%	21-40%	0-20%
Customer Complaints (O'Byrne, Key Performance Indicators for Supply Chain and Logistics)	>5%	4%	3%	2%	1%
Injuries and Illnesses	>30%	15-29%	6-14%	1-5%	0%
Employee Turnover	>30%	25-30%	15-24%	5-10%	<5%
Employee Training	<9%	10-14%	15-20%	21-25%	>26%
Labor Productivity	<19%	20-49%	40-59%	60-79%	>80%
Delivery Cost	>65%	56-65%	46-55%	35-45%	<35%
Quality of Product	<5%	5-7%	8-9%	10-12%	>12%
CO_2 Emission (gCO_2/tonne-km) (Alan McKinnon, based on data from Coyle, 2007)	>56.8	52-56.8	49.9-51.9	48-49.8	<48.0
Employment Rate	<19%	20-49%	40-59%	60-79%	>80%
Air Emission	>10%	8-10%	6-7%	4-5%	<3%
Noise Level (>80 db)	>10%	8-10%	6-7%	4-5%	<3%

The third step is done by weighting the indicators through Hierarchical Additive Weighting Method (HAWM). This method establishes a hierarchical attribute with given level of criteria. In order to calculate weighting, a pairwise comparison matrix is an important approach to compare each criteria of ratio weighting (Saaty, 1977) as shown in Table 3. The supply chain members (suppliers, manufacturers, employees, customers and communities) have different indicators' weight for performance measurement. After pairwise comparisons, Geometric Mean is used to calculate the obtained weights of indicators.

Table 3. Pairwise Comparison Matrix Which Holds the Preference Values

	X_1	X_2	X_3
X_1	W_1/W_1	W_1/W_2	W_1/W_3
X_2	W_2/W_1	W_2/W_2	W_2/W_3
X_3	W_3/W_1	W_3/W_2	W_3/W_3

where W_i = Weight of Indicators i
X_i = Indicators i

For example, to calculate weights of indicators for economics dimension, there are four indicators such as net profits, manufacturing cost, on-time delivery and productivity, as described in Table 4.

Table 4. Example of Pairwise Comparison Matrix for Economics Dimension

	Net Profits	Manufacturing Cost	On-time Delivery	Productivity
Net Profits	1	3	7	5
Manufacturing Cost	1/3	1	5	3
On-time Delivery	1/7	1/5	1	3
Productivity	1/5	1/3	1/3	1

Table 5 shows the steps to calculate weights of indicator by geometric mean. The weight of net profit is the maximum weight of indicators for the economics dimension for the manufacturer with a weight of 0.5692.

Table 5. Example of Geometric Mean

Indicators	**Geometric Mean**		**Weight**
Net Profit	$[(1)*(3)*(7)*(5)]^{1/4}$	= 3.2011	0.5692
Manufacturing Cost	$[(1/3)*(1)*(5)*(3)]^{1/4}$	= 1.4953	0.2659
On-time Delivery	$[(1/7)*(1/5)*(1)*(3)]^{1/4}$	= 0.5411	0.0962
Productivity	$[(1/5)*(1/3)*(1/3)*(1)]^{1/4}$	= 0.3861	0.0687
	Total	5.6236	1.0000

Last but not the least, overall sustainable supply chain performance score is obtained by using linear aggregation method, as shown in equation 1.

$$\text{Overall sustainable supply chain indicator} = \sum(W_i * X_i), \quad (1)$$

where W_i = Weight of Indicators i
X_i = Normalized Values i

Following the four steps to create the composite index, the numerical examples based on data of Thai Sugar Industry are shown in Table 6. The examples present measured values, rating scales, normalized valued, weights and results. The result of net profit is given as an example to calculate the sustainable supply chain index. First step is actual value of net profits which is 11.60%. Then, the actual value is converted to rating scale based on measurement level (Table 2) that gives a rating scale of 3. Then the rating scale is calculated and a normalize value of 0.75 is obtained. Third step is the calculation of indicators' weight that offers a weighting value of 0.5692. Finally, the result of net profit indicators is calculated via equation (1) that gives a result value of 0.4269.

Overall sustainable supply chain performance assessment with the composite index is done by aggregating the results of each indicator, as shown in Table 7. The results categorize the three groups of supply chain stakeholders comprising of suppliers, manufacturer, customers and community. The overall sustainable supply chain score for manufacturers is 55.61%. The other obtained score of 80.97% and 75.00% from the composite index correspond to suppliers and customers and communities, respectively. As an observation, the manufacturer is the stakeholder with the least sustainable supply chain performance. The ratio of the economic, environment and social dimension are 21.94%, 11.71% and 21.96% respectively. The environmental dimension has the highest ratio as manufacturer's management would like to improve energy usage, water usage, electricity usage, air emission and waste minimization.

For suppliers, the overall sustainable supply chain score is 80.97% comprising of ratios for the economic, environment and social at 26.30%, 21.33% and 33.33% respectively. The environmental dimension which means that suppliers would need to improve their processes to reduce environmental impact. However, customers and the community have ratios of 25.00% for the economic dimension, 33.33% for the environment dimension and 16.67% for the social dimension, it is possible that the relatively low ratio for the social dimension is that there is a bias due to the fact that the respondents are the social dimension in the proposed framework.

Table 7. Overall Sustainable Supply Chain Index

Supply Chain Members	Sustainable Dimension			Overall Sustainable Supply Chain
	Economics	Environment	Social	
Manufacturers	0.2194	0.1171	0.2196	0.5561
Suppliers	0.2630	0.2133	0.3333	0.8097
Customers and Communities	0.2500	0.3333	0.1667	0.7500

Table 6. Sustainable Supply Chain Indicators

Dimensions	**Measurements**	**Indicators**	**Formula**	**Measured Values**	**Rating Scales**	**Normalized Values**	**Weights**	**Results**
Indicators for Manufacturers								
Economics	Profitability	Net Profits	Net Profits Margin	11.6%	3	0.75	0.5692	0.4269
	Cost	Manufacturing Cost	(Manufacturing Cost per Product Unit/ Total Cost per Unit) *100	77.93%	1	0.25	0.2659	0.0665
	Timeliness	On-time Delivery	(Numbers of On-time Delivery/ Total of Purchase Orders) *100	99%	4	1	0.0962	0.0962
	Productivity	Productivity	(A Worker Time on Productive Activities) *100 / (The Total Time Available for Productive Work)	85%	4	1	0.0687	0.0687
Environment	Energy Usage	Energy Use	Ethanol Use for Production *100 / Total Generated Ethanol	80%	1	0.25	0.2550	0.0638
	Resource Consumption	Water Use	Water Use for Production *100 / Total Water	80%	1	0.25	0.2550	0.0638
		Electricity Use	Electricity Use for Production*100 / Total Generated Electricity	80%	1	0.25	0.2824	0.0706
	Emissions and Wastes	Air Emission	Energy Input *100 (Fuels) / Energy Output (Electricity)	50%	1	0.25	0.0725	0.0181
		Waste Minimization	(Waste Disposed/ A Tonne of Cane Processed Per Year) *100	39%	4	1	0.1351	0.1351
Social	Customer Satisfaction	Customer Complaints	Numbers of Complaint *100 / Numbers of Purchase Order	5%	1	0.25	0.2719	0.0680
		Complaint from Local Communities	Numbers of Complaint from Local Communities *100 / Numbers of Purchase Order	5%	1	0.25	0.1831	0.0458
	Health and Safety	Injuries and Illnesses	Work-related Injuries and Illnesses Rate	5%	4	1	0.1042	0.1042

Dimensions	Measurements	Indicators	Formula	Measured Values	Rating Scales	Normalized Values	Weights	Results
	Employee Satisfaction	Employee Turnover	Annual Employee Turnover Rate	10%	4	1	0.0293	0.0293
		Employee Training	Percentage of Numbers of Training Hours per Year	25%	4	1	0.0754	0.0754
		Labour Productivity	Labour Productivity Rate = Total Output / Total Productive Hour	70%	4	1	0.3361	0.3361
Indicators for Suppliers								
Economics	Cost	Delivery Cost	(Delivery Cost per Product Unit/ Total Cost per Unit)*100	20%	5	1	0.1884	0.1884
	Timeliness	On-time Delivery	(Numbers of On-time Delivery/ Total of Purchase Orders) *100	90%	1	0.2	0.0810	0.0162
	Quality	Quality of Product	Percentage of Commercial Cane Sugar (CCS)	10%	4	0.8	0.7306	0.5845
Environment	Energy Usage	Energy Use	$\frac{\text{Fuel Use Per Time}}{\text{Total Fuel Use}}$	50%	3	0.6	0.9	0.5400
	Emissions and Wastes	CO_2 Emission	Fuel Consumption x Fuel Emission Conversion Factor [Tonnes CO_2 emissions = liters x kg CO_2 per liter fuel / 1,000]	37.7	5	1	0.1	0.1000
Social	Customer Satisfaction	Customer Complaints	$\frac{\text{Numbers of Complaint from Manufacturing *100}}{\text{Numbers of Purchase Order}}$	5%	1	1	1	1.0000
Indicators for Customers and Communities								
Economics	Employment	Employment Rate	(Local Workers / Total Workers)*100	50%	3	0.75	1	0.7500
Environment	Emissions and Wastes	Air Emission	Frequency of Concentration of Total Suspended Particulate (TSP) Increase Level per Year	4%	4	1	1	1.0000
Social	Noise Pollution	Noise Level	Frequency of Noise Increase Level per Year	8%	2	0.5	1	0.5000

The section hereover described how the sustainability of a supply chain can be evaluated. Manufacturing firms need to consider threes groups of supply chain stakeholders comprising of suppliers, other manufacturers, customers and the community. Then, a composite index can be developed to represent the overall sustainable performance of the supply chain. The development of the composite index consists of normalization, weighting and aggregating methods. In conclusion, it is expected that the proposed framework will help supply chain stakeholders improve their respective processes by reducing cost and increasing value among members.

4. Conclusions

This manuscript discussed sustainable supply chain performance, which encompasses stakeholders that are suppliers, manufacturers, customers and the community. The proposed sustainable supply chain performance measurement highlights 14 indicators based on economic, environmental and social dimensions in order to assess sustainable supply chain. A composite index is further developed to represent overall sustainable supply chain performance. There are four steps to develop a composite index, which are (1) measuring value (2) normalization method (3) weighting of indicators (4) aggregation method. In this research, a numerical example is used to illustrate how to create a composite index based on Thai Sugar Industry case study. The obtained results offer an overall sustainability score of 55.61%. for manufacturer. The other with 80.97% and 75.00% in the composite index correspond to suppliers and customers and the community, respectively. The manufacturer has the least overall sustainability score. This means that the manufacturer need to improve its processes in order to increase current performance. The proposed overall sustainability score can help identify critical points between supply chain stakeholders.

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