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► To cite this version:

Salinee Santiteerakul, Aicha Seklouli-Sekhri, Abdelaziz Bouras. Sustainable Supply Chain Management Performance Evaluation Approaches: A Comparative Analysis. Colloque SIL 2011, Dec 2011, CASABLANCA, Morocco. hal-04191462

HAL Id: hal-04191462

<https://hal.science/hal-04191462>

Submitted on 30 Aug 2023

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Sustainable Supply Chain Management Performance Evaluation Approaches: A Comparative Analysis

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Context of this research work:

Because of we are facing the era of the energy challenges and potentially extreme climate change. Thus organizations cannot focus only on their business outcomes but they should focus on impacts to environmental and other stakeholders. Organizations were pressured by customer, government, and other stakeholders to take into account that sustainability performance is one of business core competitive. When the focal organization is pressured, it usually passes this pressure on to supplier. Here, one distinctive feature of sustainable supply chain management emerges. In order to survive and succeed, organizations usually use performance measurement system as a monitoring tool to determining their state and setting their direction to achieve business goals. But the limited of sustainability performance implementation can be observed. One of possible reason is sustainability is an immaterial value which eludes a precise mathematical definition or economic monitoring. Our research work aims to develop performance measurement tool for evaluating sustainability performance of supply chain. However, there are various approaches to measure sustainability of organization and supply chain but these existing approaches cannot be used as such to evaluate the sustainability in supply chain. In order to develop an appropriate measurement tool, we have to review the existing approaches to enhance conditions and limitations. Hence, this paper provided a systemic analysis of existing approaches based on performance measurement system design. The results of this paper lead to the directions of future research to design sustainable supply chain performance measurement system.

Abstract

This paper aims to analyze existing approaches to evaluate the performance of sustainable supply chain management (sSCM) by comparative study. Performance measurement systems (PMS) design and performance criteria are used as an analysis framework. PMS design consists of three different levels e.g. the individual performance measures, the set of performance measures, and the relationship between the PMS and the environment. Organizations evaluate their own supply chain sustainability performance through performance measurement approaches based on management system (either standards or guideline), performance measurement models, or reporting systems. Four categorized existing approaches, which are using management systems, using performance measurement system model, using reporting system and others approaches, were analyzed based on performance measurement system design framework. The result of comparison study found that none of existing approaches can solve the criticism of sustainability supply chain performance measurement. The directions of future research to design performance measurement system for evaluating sustainability supply chain performance have been enhanced in this paper.

Key words— sustainable supply chain, performance measurement, measurement system criteria, and performance model

I. INTRODUCTION

After the Brundtland Commission defined the “sustainability” as “development that meets the needs of the present without compromising the ability of future generations to meet their needs” (World Commission on Environment and Development, 1987), organizations have pressed to perform in accordance with established by society with the concept of sustainability. According to this commission, Elkington (1998) developed the idea of the triple bottom line (TBL) that considers and balances economic, environmental and social goals from a microeconomics standpoint. TBL has been popularized since the mid of 1990s as a framework for organizations to translate the concept of sustainability development into the operation of the organization.

Organization sustainability is a new area of study and

many researchers have tried to clearly define the sustainability terminology. Moreover, most researchers do not provide definitions but attempt to explain what companies are supposed to do to achieve sustainability (Bourne et al 2002; Heuerman and Olson 2004, Coelho 2005). But focusing only on organization sustainability is not enough because organizations become more dependent on their supply chains and/or networks – hence the rise of research exploring the issue of sustainability in supply chain (Beamon 1999; Carter and Rogers 2004).

If the improvement of business performance is to be achieved, improved methodologies for the development and implementation of performance measurement systems (PMS) that take sustainability principles into account are necessary (Coelho et al 2002). There are various approaches to measuring, monitoring, and

assessing progress of either organization or supply chain towards sustainability e.g. using management systems (MS) standards (International Organization for Standardization (ISO)), MS guidelines, performance evaluation approaches, and reporting systems. But this various numbers of existing approaches leads organizations to establish a well-structured performance measurement process or system for achieving sustainability. Thus, work aims to analyze the existing approaches for measuring sustainability performance of supply chain and to enhance a framework for performance measurement model in term of sustainable supply chain.

This paper is structured into four main sections. First, the literature on supply chain performance measurement systems in the context of sustainable supply chain management (sSCM) is presented and the existing sSCM models are discussed. Then methodology section explains a comparative analysis framework and process. Finally, the findings from the existing sSCM model are presented and discussed.

II. LITERATURE REVIEW

A. Supply Chain Performance Measurement Systems

According to Neely et al. (1995), performance measurement is defined as the process of quantifying effectiveness and efficiency of action. Effectiveness is the extent to which customers' requirements are met while efficiency measures how economically a firm's resources are utilized when providing a pre-specified level of customer satisfaction. Performance measurement systems are described as the overall set of metrics used to quantify both the efficiency and effectiveness of action.

Neely et al. (1995) categorized performance measurement system into three levels: the individual metrics; the set of measures or performance measurement as an entity; and the relationship between the measurement system and the internal and external environment in which it operates. Some of the principal considerations they offered for analyzing performance measurement systems are illustrated in Table I.

TABLE I
PERFORMANCE MEASUREMENT LEVEL AND KEY CONSIDERATIONS

Level	Considerations
<i>Individual performance measures</i>	What performance measures are used? What they are used for? How much the cost? What benefit do they provide?
<i>Performance measurement systems</i>	Have all the appropriate elements (internal, external, financial, non-financial) been covered?

Level	Considerations
	Have measures that relate to the rate of improvement been introduced? Have measures that relate to the long-term and short-term objectives of the business been introduced? Have the measures been integrated, both vertically and horizontally? Do any of the measure conflict with one another?
<i>Relationship with internal and external environments</i>	Do the measures reinforce the firm's strategy? Do the measures match the organizational culture? Are they consistent with the recognition and reward structure? Do some measures focus on customer satisfaction? Do some measures focus on what the competition is doing?
Source: content abridged from Neely et al. (1995)	

Neely et al. (1995) identified a number of approaches to performance measurement, including: the balanced scorecard (BSC) (Kaplan and Norton 1992); the performance measurement matrix (Keegan et al. 1989); performance measurement questionnaires (Dixon et al. 1990); criteria for measurement system design (Globerson 1985); and, computer aided manufacturing approaches. Rather than performance measurement frameworks, other authors preferred to provide criteria for performance measurement system design. The suggested performance measurement criteria from Globerson (1985); Maskell (1989), for example, are as following:

- Performance criteria must be chosen from the company's objectives
- Performance criteria must make possible the comparison of organizations which are in the same business
- The purpose of each performance criterion must be clear
- Non-financial measures should be adopted
- The measures should be simple and easy to use
- The measures should provide fast feedback
- The measured should be designed so that the stimulate continuous improvement rather than simply monitor

The overview of performance measurement provided by Neely et al. (1995) has been widely cited in recent research into supply chain performance measurement systems and metrics (Beamon 1999; Beamon and Chen 2001; Gunasekaran et al. 2001, 2004, Shepherd and Günter 2006).

Because of the complexity of supply chains, collating and delineating performance metrics is a difficult task

(Shephard and Günter 2006). Many researchers attempted to systematically collate measures for evaluating the performance of supply chains. Moreover, there is a disputation over the most appropriate way to categorize them. For example, they have been grouped according to:

- Whether they are qualitative or quantitative (Beamon 1999; Chan 2003)
- What they measure: cost and non-cost (Gunasekaran 2001); quality, cost, delivery, and flexibility (Schonsleben 2004); cost, quality, resource utilization, flexibility, visibility, trust and innovativeness (Chan 2003); resources, outputs and flexibility (Beamon, 1999); supply chain collaboration efficiency and configuration (Hieber 2002); and, input, output and composite measures (Chan and Qi 2003)
- Their strategic, operational or tactical focus (Gunasekaran et al 2001)
- The process in the supply chain they relate to (e.g. Chan and Qi 2003; Huang et al. 2004; Stepherns 2001)

This paper analyzed group of performance metrics systematically by using Neely et al. (1995) PMS design as a framework and described in *topic A* of methodology section.

The critical issues of supply chain performance measurement are:

- Lack of considering supply chain relationships and the supply chain as a whole (Lambert and Pohlen, 2001). However, the management of the entire supply chain performance is indeed very difficult and, may be, not in existence (Wong and Wong 2007; Banomyong and Supan 2010).
- The paucity of qualitative metrics and non-financial measures of innovativeness and customer satisfaction should be also addressed.
- Human resource management and modern manufacturing practices should be included into supply chain performance measurement system design
- The factors influencing the success or failure of attempt to implement measurement systems for supply chain should be investigated
- Treating measurement systems as dynamic entities that respond to environmental and strategic changes

B. Sustainable SCM Performance Measurement

Sustainable Supply Chain Management (sSCM) has been defined by Carter and Rogers (2004) as *the strategic achievement and integration of an organization's social, environmental and economic goals through the systematic coordination of key inter-organization business processes to improve the long-term economic performance of the individual company and its value network*. This definition of sSCM is based on the triple bottom line and the four supporting facets of sustainability – risk management, transparency, strategy, and culture.

While supply chain performance measurement system has been developed to achieve the critical issues as explained in topic A of literature review section, organizations and their supply chains have been pressed to more responsible to their environmental and social impacts. Thus organizations have to adopt sustainability management into their management system. There are various approaches to measuring, monitoring, and assessing an organization's progress towards sustainability e.g. using standards and codes, sustainability indicators, metrics for sustainability performance. The approaches, which organizations used to evaluate their sustainability performance, can be grouped into four groups:

- Using management system (MS) as standard or guideline for implementing and evaluating sustainable supply chain management concept.
- Using performance measurement system (PMS) model as a tool for evaluating sustainability performance.
- Using reporting systems as guideline for evaluating sustainability performance
- Using others approaches such as mathematical models

C. Existing approaches to measure sustainability performance

1) Using management system (MS)

For using MS, the most widely implemented are the ISO standards. The MS which relate to sustainable supply chain management can be grouped into three categories following the core dimensions of sustainable development concept: (1) quality management system (e.g. ISO 9001:2000, ISO 9004: 2000, ISO 31000: 2009, ISO 28000: 2007) which relate to economic performance), (2) environmental management system (e.g. ISO14001, ISO14004, ISO14301) which relate to environmental performance and (3) standards relate to social performance which are work health and safety (WHS) management system (e.g. OHSAS18001, and

AS/NZS 4801:2001) and corporate social management system (e.g. ISO26000, SA8000, AA1000).

Organizations do not directly evaluate sustainability performance through these management systems but they can adopt and integrate sustainable development concept through these management systems. The analysis of using MS for adopting sustainable supply chain management will be discussed in section IV.

2) *Using performance measurement system (PMS)*

There are various PMS model as a tool for evaluating organization performance and the best-known ones such as the BSC (Kaplan and Norton, 1996) or the EFQM Excellence Model (EFQM, 2010). Mainly geared towards measuring autonomous entities (companies, subsidiaries, business units, etc.), these models did not take the complexity of supply chain into account. Nevertheless, supply chain performance measurement models developed in recent years include Supply Chain Operation Reference (SCOR) model (Lockamy and McCormack 2004), Global Supply Chain Forum (GSF) (Cooper et al. 1997), quick scan audit methodology (Naim et al. 2002), SCM logistics scorecard (LSC) (Arashida et al., 2004), Supply Chain Assessment Tool (SCPAT) (Banomyong and Supan 2010), etc. There are two solutions to use PMS model as a tool for evaluating sustainability performance:

1. Integrate or add sustainability aspect into existing PMS model, for example, Figge et al. (2002) developed the sustainability balanced scorecard (SBSC) for linking sustainability management to business strategy. SBSC has been formulated by classified and integrated environmental and social aspects into the scorecard system. Moreover, Figge et al. (2002) added “non-market” perspective into the balanced scorecard. Thus SBSC has five performance perspectives: financial, customer, internal process, learning and growth, and non-market perspective. Environmental and social aspects have been integrated according to their strategic relevance in each perspective. Another PMS model which added sustainability aspect is SCOR model and called “Green SCOR”. (SCC, 2008). Green SCOR provides a framework for structuring and communicating environmental supply chain management programs and also includes risk management processes, practices, and performance indicators.
2. Developing new sustainability performance metrics for organization level such as eco-efficiency (WBCSD), specific sustainability

indicators (Delai and Takahashi, 2011; Jain 2005) or supply chain level such as Lowell Center for sustainable production (LCSP) indicator (Veleva and Ellenbecker 2001).

3) *Reporting Systems*

Triple bottom line approach from Elkington (Elkington 1997) and Global Reporting Initiative (GRI) (Global Reporting Initiative – GRI 2002; Jung et al. 2001; Pojasek 2001) are examples of performance reporting used as a framework by organizations for sustainability performance measurement. GRI is built over the bottom line approach (Coelho 2005). About 68 percent of the Global 250 firms generated a separate annual sustainability report in 2004 that considered environmental, social, and economic issues. In addition 80 percent of these reports discuss supply chain-related issues (Carter and Rogers, 2008).

There are 6 performance aspects in GRI report systems: economic, environmental, labor practices and decent work, human rights, society, and product responsibility. GRI provides performance indicators in term of quantitative and qualitative in each aspect. Though organizations cannot complete all of indicators item of GRI because there is a large number of indicators in this report guideline (6 performance aspects, 34 metrics, 84 indicators and more than 100 sub-indicators), but it has emphasized that the GRI report approach is the best one available for companies that want to report according to sustainability principles (Coelho 2005).

The criticisms of GRI are: the approach gives conditions to organizations to know ‘what’ to do but not ‘how’ to develop reporting process (Byren et al. 2002; Pojasek 2001), organizations cannot justify its use if they do not interconnect the GRI report with their performance evaluation and management system (Coelho 2005), there are no examples of integrated metrics (Hussey et al. 2001)

4) *Using others approaches such as decision-making tool*

One of criticisms of measurement systems designed to evaluate the performance of supply chain is should be balanced between financial and non-financial performance meanwhile non-financial performance involves relevant intangible dimensions that include qualitative indicators and human judgment. Hence, researchers have attempted to adopt a systemic and balanced approach towards designing performance measurement systems for supply chains (Shephard and Günter 2006). Decision-making tools such as analytical hierarchy processing (AHP), fuzzy set, or fuzzy logic

methodology are used to measure supply chain performance (Chan 2003; Chan and Qi 2003; Erol et al. 2011)

Sustainability supply chain performance context addressed economic, environmental, and social aspects of sSCM. Especially social aspect is difficult to measure (Székely and Knirsch, 2005). Erol et al. (2011) proposed a new framework for measuring sustainability performance of supply chain using fuzzy multi-criteria method. They suggested selecting sustainability indicators by consider these factors: relevance to key objectives, measurability data, data availability, administrative burden, reliability of information source, and cost of collecting data. The proposed sustainability performance metrics categorized by triple bottom line dimension (economic, environmental and social, which consists of 10, 12, and 15 indicators respectively). The importance levels for the indicators were calculated using fuzzy entropy method. Then, the aggregated performance indices with respect to each aspect of sustainability were computed by using fuzzy Multiple Attribute Utility Theory (MAUT). Moreover, this model provided alert levels for decision makers to satisfy their further needs.

From this literature review section, we found appropriate criteria and critical issues to design supply chain performance measurement system. Besides these findings and the existing approaches that organizations adopted sustainable management in their companies and supply chain, we structured PMS analysis framework to compare existing approach in section III.

III. PMS COMPARATIVE FRAMEWORK

This paper used a performance measurement system consideration design from Neely et al. (1995) as a framework for analyzing four categories of existing performance measurement system (using MS, PMS, reporting system and others approaches) in a context of sustainable supply chain management. Performance metrics and indicators are defined and categorized in an individual performance measures level. The key dimensions of manufacturing's performance can be defined in terms of quality, delivery speed, delivery reliability, price (cost), and flexibility (Neely et al. 1995). However there is more complex metrics in term of supply chain management performance and sustainability performance because supply chain does not focus only manufacture entity but covers others all of entities since upstream to downstream such as transporter, distributor, retailer, and customer entities. Researchers attempted to categorize group of supply

chain performance metrics. Existing supply chain performance measurement systems have different characteristics both in term of group of metrics and methodology. Moreover, to measure sustainability performance of supply chain makes performance metrics categorization more complicate.

Thus this paper analyzed structure of sustainability performance metrics. In addition, some existing PMS provided indicators for sustainability metrics. Type of indicators was analyzed in term of quantitative and qualitative indicators. Reflection of indicators was be analyzed in term of leading or lagging indicators. *Leading indicator* is an indicator that measures performance before the business or process result starts to follow a particular pattern or trend. Leading indicators can sometimes be used to predict changes and trends. *Lagging indicator* is an indicator that measures performance after the business or process result starts to follow a particular pattern or trend. Lagging indicators confirm long-term trends, but do not predict them.

The second level, performance measurement systems, analyzed balancing between financial and non-financial, and short-term and long-term performance. Moreover, supply chain maturity was analyzed to measure scope of supply chain performance consideration. Supply chain maturity categorized into organization, partnership and whole supply chain level.

Relationship with internal and external environment has been considered organization or supply chain performance with internal environment, which defined as organization's strategies and cultures, and external environment, which consists of two elements: customer and competitor. Some existing model formulated performance metrics from organization's strategy thus relation between strategy and performance metrics was considered as a relationship between PMS model and internal environment. Some existing model can reflects customer's satisfactions or can benchmark performance with others competitors thus the relationship between performances attribute with customer and competitor was analyzed in this level. Analysis issues of three levels performance measurement system are summarized in Table II.

TABLE II
ANALYSIS ISSUES BY PMS LEVEL

Level	Analysis Issues
<i>Individual performance measures</i>	<ul style="list-style-type: none"> • Hierarchy or level of metric categorization • Type of indicators (quantitative and qualitative) • Reflection of indicators to performance aspect (leading or lagging indicator)
<i>Performance measurement systems</i>	<ul style="list-style-type: none"> • Balanced between financial and non-financial aspects, short-term and long-

<i>Relationship with internal and external environments</i>	term.
	• Supply chain maturity level (organization, partnership, whole supply chain)
	• Related with organization and/or supply chain strategy
	• Link between performance attribute with customer satisfaction or competitor performance

IV. COMPARATIVE ANALYSIS

This section introduces the comparative analysis of the existing approaches to measure sustainable supply chain performance following analysis issues from section III. This paper categorized the existing approaches into four categories as explained in *topic C* of section II, which are using MS, PMS model, reporting system and other approaches.

A. Management systems

This paper divided management systems that involve sustainability and supply chain context into three groups following sustainable dimensions: economic, environmental and social. Category of sustainable dimension and management systems are illustrated in table III.

Organizations do not directly evaluate sustainability performance through these management systems but they can adopt and integrate sustainable development concept through these management systems. These management systems include standard and guideline requirements from existing management systems.

All of management systems use PDCA principle even do not provide performance metrics and indicators but organizations are required to establish and maintain procedures to monitor and measure their performance in Check and Action phase (except ISO 14301, which is a standard that gives guidance on the design and use of environmental performance evaluation (EPE)). Moreover, these MS provide organization know 'how' to manage and improve their performance.

TABLE III
CATEGORY OF SUSTAINABLE DIMENSION AND MANAGEMENT SYSTEM

Sustainable Dimension	Considered Management System
<i>Economic</i>	Quality management system: • ISO 9001:2000, ISO 9004: 2000 Risk management system: • ISO 31000: 2009 Supply chain security management system: • ISO 28000: 2007
<i>Environmental</i>	Environmental management system: • ISO 4001, ISO 4004, EMAS, ISO14301
<i>Social</i>	Workplace, health and safety management system: • AS/NZS 4801:2001, OHSAS 18001:1999 Corporation Responsible management system: • SA 8000, AA 1000, ISO 26000

1) Economic dimension

Economic or generic performance dimension relate with quality, risk management and supply chain security performance. The well-known quality management standard is ISO 9001:2000. ISO 9001:2000 promotes the adoption of a process approach when developing, implementing, and improving the effectiveness of a QMS to enhance customer satisfaction by meeting customer requirements. It was developed, together with ISO 9004:2000, as a consistent pair of QMS standards which have been designed to complement each other but can also be used independently (International Organization for Standardization 2000).

ISO 31000 is the risk management: principles and guidelines. It suggests risk management framework processes and activities that should be followed to help organizations better meet their goals and objectives by using PDCA (Plan-Do-Check-Action) principle. It is non-certifiable but does provide guidance on best practices.

ISO 28000 is the specification for security management systems for the supply chain. The PDCA management systems structure was adopted in this standard. Integrate the paradigm of risk, security and supply chain management.

2) Environmental dimension

Environmental dimension relate with environmental management system (EMS). EMS determines the organization's environmental policy, objectives and targets. ISO 14001 specifies the requirements for an EMS that may be audited for certification. ISO 14004 (environmental management systems – general guidelines on principles, systems, and supporting techniques) (International Organization for Standardization 2004a) only provides guidance to help an organization establish, implement and improvement EMS.

The other recognized standard in the area is the *Eco Management and Audit Scheme (EMAS)* standard of the European Commission. (European Council 2001) Both ISO and EMAS have the same approaches to management, as they are based on the PDCA and continual improvement principles. The major differences are: to comply with EMAS have to undertake an initial environmental review before implementing and have to develop an environmental statement after each auditing, but with ISO it is not compulsory for both issues.

ISO 14301:2000 is the environmental performance evaluation guideline (International Organization for Standardization 2000). ISO 14301 provides six environmental aspects, which are the scale and nature of material and energy use, emissions, risks, the condition

of environments, the possibility of incidents, and legal regularities and other requirements to which the organization subscribes. The indicators described in ISO 14301 are divided in two types e.g. (1) environmental performance indicators (EPis) – provide information about management effort to influence the performance of organization's operation and information about performance of operation's organization and (2) environmental condition indicators (ECIs) – provide information about the condition of the environment. Both types of indicators consist of quantitative and qualitative. However, the selection of indicators is at the discretion of the organization even the standard suggests that indicators should address.

3) *Social dimension*

Social dimension relate with workplace healthy and safety management system, and corporation responsible management system. The well-known documents used by organizations in the implementation of workplace health and safety management systems are AS/NZS 48001:2001 – *Occupational Health and Safety Management Systems – Specification and Guidance for Use* (Standards Australia and Standard New Zealand 2001) and OHSAS 18001: 1999 – *Occupational Health and Safety Management Systems – Specification* (British Standards Institution 1999). These two standards have the same approaches of management, which based on the PDCA and continual improvement principles, and they do not have any substantial differences.

SA 8000 – *Social Accountability 8000* (Social Accountability International, SAI 1998) is an international standard developed by Social Accountability International, a charitable human rights organization dedicate to improving workplaces and communities. It is a workplace standard that covers key labor rights. It works within the human resources area of organizations and as a complement of the occupational, health and safety management systems. It does not address any kind of issues related to the external social responsibility of organizations.

AA 1000 – *the Institute developed Assurance Standard Guidance for Social and Ethical Accountability*, an international organization based in the UK that encourages ethical behavior in business and is based on assessment of reports against three assurance principles: materiality, completeness, and responsiveness. The standard is designed to complement the GRI. The series and framework was developed to help users to improve accountability and performance by learning through stakeholder engagement.

ISO 26000 is the guidance on social responsibility. This standard offers guidance on socially responsible behavior and possible actions; it does not contain requirements and is not certifiable. ISO 26000 provide

seven core subjects for corporate social responsibility which are: organizational governance, human rights, labor practices, fair operating and practices, environment, customer issues, and community involvement and development. This standard does not provide indicators for core subjects but provide a guideline to organization how to adopt each core subject to their organization.

All these management systems based on PDCA principles and organizations can adopt sustainability management through MS but they have to implement at least three management systems to complete all three dimension. Nevertheless, adopt at least three management systems cannot reflect sustainability performance of organization because they are not integrate these MSs into the same system. Moreover, these management systems focus on organization's performance not supply chain performance. However, implementing management system helps organization to learn how to manage and improve their performance and it is a basically approach to implement sustainability or others concept management to organization.

B. *Performance Measurement System Models*

According to two solutions for using PMS model as a tool for evaluating sustainability performance that explained in *topic B* in section II. First solution is integrating or adding sustainability aspect into existing PMS model, which are SBSC (Figge et al. 2002) and SCOR 9.0 model. Second solution is develop new sustainability performance metrics, which are eco-efficiency (WBCSD), specific sustainability indicators (Figge and Hahn, 2004; Jain 2005) and Lowell Center for sustainable production (LCSP) indicator (Veleva and Ellenbecker 2001).

1) *Adding sustainability aspect to existing PMS model*

Sustainability Balanced Scorecard (BSC)

The well-known performance measurement model is the balanced scorecard (BSC). Figge et al. (2002) developed Sustainability Balanced Scorecard (SBSC) by integrated environmental and social aspects in to the main management system of a firm. SBSC integrated environmental and social aspects by identified the environmental and social exposure of a business unit. Environmental exposure categorized into eight types: emissions, waste, material input/material intensity, energy intensity, noise and vibrations, waste heat, radiation, and direct interventions on nature and landscape. Social exposure categorized into two types: direct stakeholders and indirect stakeholders. Then

determine the strategic relevance of environmental and social aspects. In order to determine the strategic relevance, lagging and leading indicators are defined. Lagging indicators represent strategic core issues and leading indicators represent performance drivers.

Individual measures of SBSC consists of five performance metrics based on four metrics from general BSC and a new added metrics, which are: financial, customer, internal process, learning and growth, and non-market. Indicator determination based on organization strategy and objective but organizations should consider environmental and social aspects into five performance metrics.

Performance measurement system of SBSC reflects both financial (financial perspective performance) and non-financial (customer, internal process, learning and growth, and non-market perspective performance). But for supply chain maturity level implementation of SBSC is only in organization performance level because this model does not consider partnerships and supply chains sustainability performance.

Relationship with internal and external environment of SBSC can reflect customer's satisfaction because customer is the one of performance perspective. And SBSC directly reflects relationship between organization performance and strategy level because this model formulated performance metrics and indicators from organization's objectives.

SCOR 9.0 model

SCOR, has been developed in 1996 by the Supply Chain Council (SCC), is a supply chain process reference model containing over 200 process elements, 550 metrics, and 500 best practices which including risk and environmental management in the ninth version (SCOR9.0). It can be regarded as a closely related concept for sSCM. However, it is not more consider in social dimension.

Individual measures of SCOR are constructed by five management processes, which are plan, source, make, deliver, and return. SCOR provides ten performance metrics, which are perfect order fulfillment, order fulfillment cycle time, upside supply chain flexibility, upside supply chain adaptability downside supply chain adaptability, supply chain management cost, cost of goods sold, cash-to-cash cycle time, return on supply chain fixed assets, and return on working capital. Both quantitative and qualitative indicators are proposed in each metrics and constructed by three management levels, which are strategic, tactical, and operational. Moreover, leading and lagging indicators determine by mapping indicators and metrics relationship. The risk

management metric and GreenSCOR metric are proposed in SCOR9.0, which constructed by management processes and levels but for GreenSCOR, only environmental in term of carbon emissions, air pollutant emissions, liquid waste generated, solid waste generated, and percent of recycled waste.

Performance measurement system of SCOR represents by *attribute performances*, which are reliability, responsiveness, agility, costs and assets. SCOR reflects both financial (cost and assets attribute performance) and non-financial (reliability, responsiveness, and agility attribute performance). In addition, SCOR covers whole supply chain maturity. However, it is complicate and takes a long time to complete whole supply chain performance evaluation by using SCOR.

Relationship with internal and external environment of SCOR can reflect both internal and external environment. Internal environment represents by customer-facing attribute performance, which consists of reliability, responsiveness, and agility. External environment represents by internal-facing attribute performance, which consists of costs and assets. However, risk management and GreenSCOR metrics have been not integrated with attribute performance metrics. Thus, attributes performance reflect only economic dimension of sustainable supply chain management context.

2) Developing new sustainability performance metrics

Creating sustainability performance metrics is usually used for measure sustainability performance in supply chain. The processes to develop sustainability metrics are as follow:

- Define sustainability scope
- Define an important aspect (lagging indicators) and important factors (leading indicators)
- Collecting data
- Assess sustainability performance
- Check feedback and improve

Individual measures of sustainability metric depends on determine sustainability defining process, for example, eco-efficiency is determine sustainability scope only in environmental dimension while sustainability metrics of LCSP and Delai and Takahashi (2011) cover both environmental and social dimensions. Eco-efficiency focuses on only environmental perspective of organization. This model consists of two metrics e.g. product/service value and product/service creation environmental influence metrics. Most of indicators are quantitative and this model does not define leading and lagging indicators. LCSP provides six sustainability

metrics e.g. energy and material use, natural environment, economic performance, community development and social issues, workers, and products. Indicators in this model are defined into five types of implementation indicators e.g. facility of compliance/conformance indicators, facility material and performance indicators, facility effect indicators, supply chain and product life indicators, and sustainable system indicators. However, most of suggested and implemented indicators of their case studies are facility of material and performance indicators. It means in a practical implementation, organizations still adopted sustainability performance measurement of their organization not supply chain. Delai and Takahshi (2011) proposed model consists of three sustainability metrics e.g. environmental, social and economic metrics. Each metrics contain both quantitative and qualitative indicators. Although this model does not directly defined leading and lagging indicators but developers discussed about this issued that leading indicators play an important role for long-term achievement of organization.

Performance measurement system of sustainability metrics: eco-efficiency focuses on only environmental efficiency of organization and however there are non-financial indicators but mainly consider on manufacturing process. LCSP reflects both financial and non-financial performance of organization and provides how to implement the set of indicators in a higher level (expand from organization to supply chain level). Delai and Takahashi reflects both financial and non-financial performance but this model considers only sustainability of organization not supply chain. Hence, this model can reflects supply chain maturity of organization's level

Relationship with internal and external environment of three PMS models: eco-efficiency and LCSP focus on organization's environmental impacts and organization's production sustainability respectively, thus these two models do not link sustainability performance with customer's perspective. Meanwhile, Delai and Takahashi's model considered customer perspective in social dimension as a customer relationship metric. However, all of these models are not directly enhance relationship between sustainability organizations and/or supply chain performance with their organizations and/or supply chains' s strategies

Hence, developing new sustainability PMS to measure organization and/or supply chain sustainability performance is more flexible than adding sustainable context in existing PMS model but the weakness is lacking a relationship between PMS model with internal and external environment.

C. Using reporting systems

Global Reporting Initiative (GRI) (Global Reporting Initiative – GRI 200) is the most worldwide sustainability reporting guideline (Jung et al. 2001; Pojasek 2001).

Individual measures of GRI: there are 6 performance aspects in GRI report systems: economic, environmental, labor practices and decent work, human rights, society, and product responsibility. GRI provides performance indicators in term of quantitative and qualitative in each aspect. However, GRI does not determine leading and lagging indicators.

Performance measurement system of GRI reflects both financial and non-financial performance of organization. GRI reflects supply chain maturity in partnership level by suggests organization to define their stakeholders in term of suppliers, partners, customers and local communities.

Relationship with internal and external environment of GRI reflects relationship between organizations with customer perspectives by some indicators in product responsibility performance metric and reflects relationship with organization's strategies in determining organization's policy process, which is the first process for creating sustainability report.

However, organizations cannot complete all of indicators item of GRI because there is a large number of indicators in this report guideline (6 performance aspects, 34 metrics, 84 indicators and more than 100 sub-indicators), but it has emphasized that the GRI report approach is the best one available for companies that want to report according to sustainability principles (Coelho 2005).

D. Using others approaches

This approach is similar to developing a new sustainability PMS model but may adding aggregation or integration indicators method for evaluating sustainable supply chain performance. Moreover, some researchers, for example, combine decision-making tool with the evaluation model (Chan 2003; Chan and Qi 2003). This approach can reduce obstacles about integrating qualitative with quantitative performance measures, which is a criticism of supply chain performance measurement. For this topic, we use Erol et al. proposed model (Erol et al. 2003) as an example to analyze characteristics of sustainability performance.

Individual measure of Erol's model consists of three sustainability performance metrics, which are environmental, social and economic performance, which consists of 10, 12, and 15 indicators respectively. Indicators both in quantitative and qualitative are

assigned. There is not a determination of leading and lagging indicators in this model.

Performance measurement system of Erol's model reflects both financial and non-financial performance of organization. Erol's model reflects supply chain maturity in partnership level because this model uses some indicators to measure an effectiveness of stakeholder involvement and supplier's issues.

Relationship with internal and external environment of Erol's model does not reflect relationship between organizations with customer perspectives and also does not reflect relationship with organization's strategies.

V. CONCLUSION

The purpose of this paper was to present existing approaches to measure sustainable supply chain performance by using a systemic comparative framework. Criticism of sustainable supply chain performance measurement systems were made on existing performance measurement approaches such as complicated analysis, implement difficulties, unbalanced between financial and non-financial performance, unrelated with customers or organization's objectives. And we found that none of existing approaches can solve all of these criticisms. Using sustainable management through existing management system is a starting point for companies to integrate sustainability into their current performance measurement system and this approach help them to embed it into daily activities and to forge a sustainability culture. But it can implement to their organization not supply chain. In addition, there is no management system that includes all environmental, social and economic perspectives. It means organizations should be implement at least two management system for achieving their sustainability goals. The existing approaches for adding sustainability context to existing PMS model is still lack of link relationship between performance measurement model and supply chain perspective, for example: SBSC model. In the other hand, existing PMS model such as SCOR 9.0, which includes supply chain perspective in consideration, does not contains social dimension in the model. Using others approaches such as decision-making tools for evaluating sustainability performance in supply chain can reduces criticism of aggregating and integrating qualitative indicators with quantitative indicators. However, the existing models do not consider relationship between sustainability with customer and organization's strategies perspective.

The result of these paper leads to the directions for designing sustainable supply chain performance

measurement model. We found that sustainability measurement in supply chain context has not yet fully matured and is still facing some important challenges. Future research for sustainable supply chain performance measurement system should consider relationship between sustainability performance with organization strategies and objectives, define leading and lagging indicators for enhancing key success indicators to achieve a long-term sustainable supply chain, include using decision-making or mathematical model to integrate and aggregate qualitative indicators (especially in social dimension) leads to more precise for evaluating sustainability performance. Moreover, the main criticism of measure sustainability in supply chain is difficulties to evaluate sustainability along supply chain, not only organization or partnership level. Hence, future research should more focus on how performance measurement model can evaluate sustainability across organizations in their supply chain.

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