A framework for developing performance measurement systems for "green" supply chain management strategies

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Abstract

As environmental issues are continually and rapidly emerging as one of the most crucial topics in strategic manufacturing decision making, the formulation of "green" performance management systems is very important. This research seeks to introduce and explore green performance measurement frameworks that exist in various real-world case studies that are found in literature. The study yielded a set of four taxonomic performance measurement systems that are applicable in specific contexts of manufacturing supply chain strategies. Moreover, specific green performance metrics are provided in respect of the identified green manufacturing strategies. Implications of the application of each performance management system on existing manufacturing policies are evaluated, giving practical managerial insights. The study forms an essential framework for the decision maker to rapidly develop a suitable performance system in a green manufacturing environment, within a reasonable time frame.

Keywords

Performance measurement, "green" supply chain management, environmental performance, environmental management

1 INTRODUCTION

Environmental issues are rapidly becoming one of the most important topics in manufacturing supply chains. Apart from low cost, short lead time and high quality, managers consider improvements in environmental performance a basic competitive priority [1] [2] [3]. The ever-increasing "green" concerns in the market and the ensuing green movements have forced decision makers to manage their organisational performance not only from the economic stand point, but also from the ecological perspective. Regulatory bodies in various countries enforce recovery of product packaging [4]. For instance, a number of automotive industries have introduced product recovery and take-back strategies [5].

The introduction of green strategies for environmental management bears a significant impact on the choice and successful implementation of an appropriate performance measurement system. In this view, the linkage of green strategies to performance measurement systems is a serious challenge to supply chain managers. Precisely, the implementation of green strategies requires changes in the following areas:

(i) *Procurement policies*: new environmental performance requirements require significant modifications in material supply procedures;
(ii) *Product technology*: new environmental targets often require new product structures, design, components, and materials;
(iii) *Process technology*: new green strategies require environmental friendly technologies such as closed-loop and cleaner technologies;
(iv) *Logistics and distribution*: environmental policies may require new ways of managing physical flows of goods and supply chain collaboration.

Due to the strategic importance of green issues and environmental performance management systems (PMSs), much attention has been focused on (i) analysis and enhancement of green strategies available to supply chain managers [3], and (ii) development of frameworks for assessing environmental performance based on physical indicators, environmental costs, and life-cycle analysis [4] [6] [7]. Studies on supply chain PMSs pointed out the need for [8] (i) organization- and supply-chain-wide coordination; (ii) every metric to take a supply chain perspective; (iii) common goal upon which each entity in the supply chain is measured and improved; and (iv) designing new non-financial and financial measures. Major concerns associated with the application of PMS across the entire supply chain include lack of understanding of the essence of inter-organizational metrics, conflicting organisational objectives leading to disagreements in the choice of performance measures, lack of standardized performance measures, and difficulty in linking measures to customer and stakeholder value.

In spite of the above issues, little attention has been paid to the design and implementation of environmental performance measurement systems

(PMSs) for specific green strategies. The concerns pointed out above arise due to different green strategies and performance management systems in different supply chains. Furthermore, different firms have different organisational objectives and capabilities. The development of appropriate performance systems, given the right green strategies, is not trivial. As such, the development of a framework for implementing performance measurement systems is imperative. Most of the frameworks in green supply chain management (GSCM) literature simply classify green strategies into re-active and pro-active strategies, which is rather too broad.

In light of the above issues, this study seeks to provide a taxonomic analysis of performance measurement, deriving from the contributions on strategic GSCM and PMSs. A taxonomic contingency framework which examines how different PMSs may be implemented in the context of specific green strategies is developed. The specific objectives of this study are as follows:

(1) To derive a taxonomy of green strategies, identifying the drivers behind their adoption;
(2) To identify the most effective PMS systems in the context of each strategy in (1),
(3) To identify PMS metrics and their respective structures.

The structure of the paper is as follows: the next section provides an overview of our research methodology. Section 3 presents the results of the research survey. Section 4 gives an overview of green supply chain management. Section 5 outlines the taxonomy of green strategies, while Section 6 presents an analysis of specific PMS measures in respect of the green strategy identified in this study. Finally, Section 7 concludes the paper.

2 RESEARCH METHODOLOGY

Green supply chain success indicators are quantifiers for assessing the efficiency and effectiveness of green supply chain management. These indicators vary between companies and industries, depending on their priorities or performance criteria. As shown in Figure 1, this research focused on surveying cases on GSCM and their respective PMSs. Cases were selected from reputable international journals, including *Sustainability*, *International Journal of Production Economics*, *International Journal of Operations and Production Management*, *Supply Chain Management*, and *Benchmarking: An International Journal*. For each case study, key areas of focus where identified, together with the drivers behind implementation of GSCM strategies. The green PMS metrics applied under specific contexts of the case studies were also investigated. A generic framework for selecting appropriate PMS metrics for different GSCM strategies was then developed. Results of the survey are given in the next section.

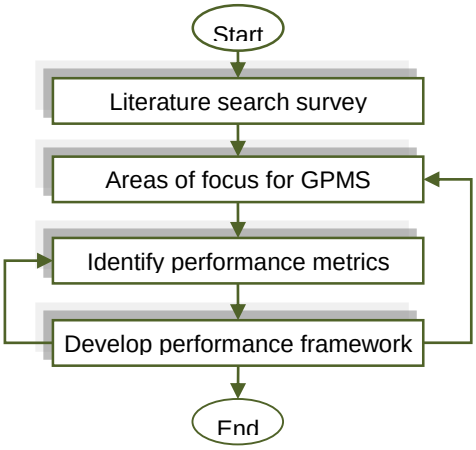

Figure 1 - Research methodology

3 RESULTS OF THE SEARCH SURVEY

The literature search survey showed that there are three key areas of focus in GSCM: (i) to improve environmental performance (ii) to improve economic performance, and (3) to promote social responsibility, i.e., to improve a firm's green image. Hence, performance metrics can be classified into:

(1) Environmental performance
(2) Economic or financial performance
(3) Social performance

Table 1 provides a summary of the performance indices identified from empirical studies in the literature.

Area of focus	Performance Metrics	Reference source
1. Environmental performance	Air emission	[10] [11] [12]
	Waste water, or water pollution	[10] [11] [12] [13] [14] [15] [7]
	Solid waste, or hazardous materials	[10] [11] [12] [16] [17] [18]
	Energy usage or consumption	[10] [11]
2. Economic performance	Reverse logistics costs	[19] [20] [21]
	Sustainability costs, energy consumption costs	[7] [14] [15] [22]
3. Social responsibility performance	Green image, customer perspective	[7] [15] [17] [21] [22]
	Percent recycling, scrap rate	[7] [14] [15] [17] [18] [19] [20] [22]

Table 1 - Overview of the identified performance metrics from empirical studies

4 GREEN SUPPLY CHAIN MANAGEMENT

Several researchers have investigated the concepts of greening the environment at strategic and operational levels. In particular, researchers have studied greening practices, including product design [24], process design [25] [26], purchasing [27], and green manufacturing practices at large [28] [29]. From these greening concepts, the environmentally-conscious practices, and the motive for organisational competitiveness, GSCM can be defined as follows:

GSCM = Green Purchasing + Green Manufacturing + Materials Management + Green Distribution + Green Logistics

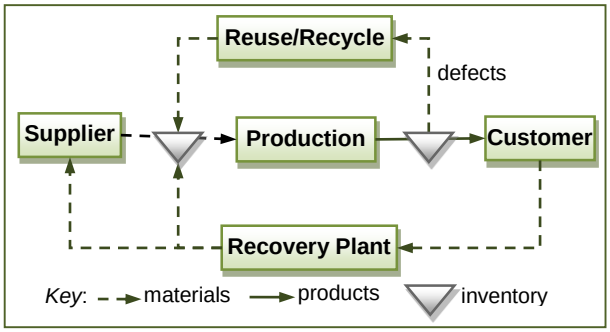

Figure 2 - Green supply chain management (adapted from Ninlawan et al., [30])

As shown in Figure 1, supply chain players such as warehouses, waste collectors, recovery plants, final treatment (landfill) and other stakeholders are involved in carrying out green activities. The figure represents a single organization's internal supply chain and its major operational elements. However, a number of organizational relationships can be integrated at various stages of the model, including customers and suppliers, as well as their chains.

Environmentally conscious practices in the supply chain range from *green design* (engineering and marketing), *green procurement* practices (purchasing environmental friendly materials and products, certifying suppliers), total quality environmental management (pollution prevention, internal performance measurement and auditing), environmental friendly packaging and distribution, to product end-of-life practices (recovery, reuse, recycle, remanufacturing). The choice and the success of these green practices depend on the objectives and capabilities of an organisation. The next section presents a taxonomy of green strategies.

5 A TAXONOMY OF GREEN STRATEGIES

The adoption of green strategies has a far-reaching and multi-dimensional impact on performance [3]. For example, the introduction of closed-loop strategies may result in (i) management complexities due to changes in logistics for product recovery and recycling leading, and (ii) multiple changes in performance measurement, and (iii) the management of operations. It is therefore necessary to identify the conditions under which these strategies are best implemented, and to analyse the performance measurement systems in light of the identified strategies.

5.1 Drivers behind GSCM strategies

The depth of the environmental awareness of an organisation will influences the perspective from which green strategies are developed. In the absence of environmental awareness, an organisation adopts a naive perspective where the enterprise takes no initiatives to improve its environmental performance. Identified internal drivers of green strategies are [3]:

- *Compliance*: the desire to ensure that products and processes comply with environmental regulations;
- *Eco-efficiency*: minimization of wastes and resource usage, while maximising environmental performance;
- *Competitive advantage*: competitive advantage through green product and manufacturing technologies and innovation;
- *Ecological/ethical concerns*: the desire to reduce industrial impact on the environment.

Total quality control, cost control, and environmental regulations have been identified as the main drivers behind an organisation's environmental perspective [31] [32] [33]. However, broadly speaking, the influence of these drivers depends on a combination of factors at industry, country and even global levels. In addition to internal drivers above, two external drivers are realised;

- *Green pressures*: customers and other stakeholders create "green" movements leading to widespread adoption of green strategies.
- *Supply chain relationship*: supply chain collaboration and relationship will always influence the company's environmental behaviour.

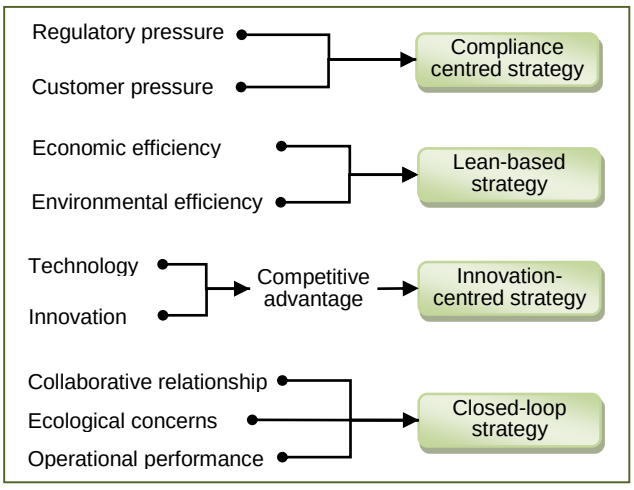

Figure 3 - Green supply chain drivers

These drivers, internal and external, are vital factors for analysing GSCM strategies (see Figure 3).

5.2 The green supply chain strategies

In view of the above internal and external drivers, four major categories of GSCM strategies are distinguished (see Figure 3):

1. *Compliance-centred strategy*. This strategy is adopted in response to environmental regulations and customer pressure. Companies may be obliged to adopt international standard systems (e.g., ISO 14001 [33]), purchasing contracts with suppliers so as to meet certain regulatory requirements;
2. *Lean-based strategy.* This is normally adopted by organisations that focus on eco-efficiency where suppliers are required to satisfy certain operations-based efficiency targets. The strategy link environmental performance with operational efficiency through waste minimization and optimal resource usage;
3. *Innovation-centred strategy*. This is adopted by companies whose objective is to keep up-to-date with changes in environmental regulations through specialised technologies, product designs, processes and strict green performance standards [28] [30];
4. *Closed-loop strategy*. This is adopted by firms in highly collaborative supply chains where companies can keep abreast with complex requirements of closed-loop supply chain and to integrate with suppliers, from design to product take-back. Material recovery, recycling and remanufacturing improve environmental performance of the entire supply chain [12] [19].

6 DEVELOPING GREEN PMS MEASURES

When developing a green PMS, the following requirements should be taken into account [3]: (i) *strategic focus*, the ability to account for long-term investment decisions and their impacts; (ii) *measurability*, the ease of measurement and assessment of green efficiency; (iii) c*ompleteness*, the ability of the performance model to account for all the relevant performance indicators for effective assessment of the firm's PMS; (iv) *timeliness*, this evaluates the time taken by the PMS to analyse collected data; (v) *cost of analysis*, the cost of resources needed to implement the PMS chosen.

Based on the characteristics of specific green strategies in this taxonomy, PMS models are developed to enhance strategic focus and measurability, while considering a good trade-off between completeness, timeliness, and cost.

Environmental performance indicators (measures) are the core requirements of a PMS for effective evaluation of the environmental performance of processes, activities and services. The taxonomy of green strategies helps in identifying the most effective performance measures and in designing the PMS structure. Performance indicators range from air emissions to energy recovery and recycling. Possible PMS designs include: (i) models which use physical indicators to describe environmental impact resulting from the strategy adopted; (ii) models based on economic indices linked with economic efficiency; (iii) models based on life-cycle analysis methods indicating the economic and physical impact of a given strategy throughout the product life cycle; and (iv) models based on an integrated perspective that indicates the effect of the adopted green strategy on shareholders' value, physical indices, and economic indices. The following section analyses performance metrics for the green strategies identified in this study [4] [5] [6].

To assess the impact of industrial processes, the following indicators are utilized;

(1) *physical indicators* - to measure, in physical terms, how the supply chain activities affect the natural environment; or,
(2) *economic or financial indicators* - to measure the variation of the life-cycle costs associated with the product in question, or,
(3) *Social indicators* – to measure the green image of a firm based on customer or stakeholder's evaluation.

Ideally, effective PMSs should basically include both physical and economic measures in an integrated framework. While physical measures provide a timely assessment of the activities of the firm, financial measures indicate how the adopted supply chain activities affect the organisation's profitability [5]. Therefore, an efficient PMS supporting the implementation of a green strategy should consider the physical environmental indicators, expressing the organisation's environment performance. These measures can be aggregated into the following categories [4] [5]:

- *Volume indices*: these assess the amount of solid wastes resulting from a firm's production operations, such as percentage of scrap, and percentage of recyclable products;
- *Process efficiency indices*: these assess the environmental efficiency of a company's operations regarding waste water, air emissions and energy consumption.
- *Design efficiency indices*: theses measure the "green" design features defining the "green" products, such as assembly time, number of materials or parts in a product, and number of levels in the bill of materials.

To monitor the firm's contribution to economic or financial value creation, the following economic features need to be considered:

- operational efficiency: costs of green manufacturing operations, materials,

(non)manufacturing overheads, direct labour, and environmental compliance audits;
- distribution costs: costs due to transportation, waste disposal and product take-back;
- price of the product as well as demand for the product;

Suggested indicators and their descriptions will be provided in the next section.

6.1 Measures for compliance-based strategies

The compliance-based strategy normally arises from the introduction of environmental regulations, or from extreme customer pressure. The strategy seeks to identify the key areas of concern in line with the organisation's capabilities, leading to the adoption of operations that ensure that the organisation meets the required environmental performance. In this respect, the adopted PMS should offer the following;

- Timely measurement of physical indices to highlight the firm's performance;
- Accurate monitoring of physical indices in order to monitor the trend of the performance.

Air emissions, waste water, solid wastes and energy consumption measures should be included in the PMS in accordance with regulations. Table 2 shows the suggested indicators and their descriptions. For environmental performance assessment, the most effective way is to benchmark the current performance with the regulation standards. When selecting among different potential solutions or programs, an aggregate indicator, derived from the above measures, can be used to evaluate the solutions. Thus, four indicators derived from these measures can be used to describe the trends in environmental performance. Specialised indices can be aggregated into these four basic categories.

The identified indicators can be used to evaluate decrease of various costs: (a) costs associated with material usage, energy usage, raw material usage, and (b) costs associated with fees paid for waste discharge, waste treatment, including transportation and distribution. These are concerned with process efficiency indices.

No.	Indicator	Description
1	Air emissions	Percentage of gas emissions into the air, e.g., chlorinated pollutants
2	Waste water	Percentage of pollutants in water, e.g., total nitrogen
3	Solid waste	Percentage of materials sent for disposal
4	Energy	Amount of energy consumed, e.g., electricity, oil

Table 2 - Compliance-based performance indicators

The compliance-based PMS is most suitable to organisations that choose to follow a passive approach to environmental performance with the objective of introducing green concepts in order to meet customer pressure, or to comply with some limiting environmental regulations. One notable negative impact of this perspective is that it offers limited competitive advantage in the presence of aggressive innovations in environmental performance. Due to its reactive nature, the passive approach often lags behind the target performance required, resulting in loss of market share. In this regard, timeliness of the PMS is crucial, especially in the presence of fast-changing regulations.

6.2 Measures for lean-based strategies

Lean-based strategies go beyond regulatory compliance through the requirement for the suppliers to meet operations-based targets. This strategy seeks to maximize economic performance and provide secondary environmental performance benefits through waste and resource use reductions. The aim is to gain dual environmental and economic performance benefits; therefore, performance indicators for lean-based strategies should include the following [4] [5]**;**

(i) physical indicators, and
(ii) economic indicators

The physical indicators correspond to the compliance-based indicators in Table 2. Table 3 lists the lean-based economic performance indicators suggested in this study.

No.	Indicator	Description
1	Material costs	Decrease of material purchasing costs
2	Energy	Decrease of energy consumption costs
3	Raw materials	Decrease of raw material costs
4	Waste treatment	Decrease of fees paid for waste treatment
5	Waste discharge	Decrease of fees paid for waste discharge
6	Transportation	Decrease of transportation related costs

Table 3 - Lean-based performance indicators

6.3 Measures for innovation-based strategies

The innovation-based strategies often lead to the introduction of new green product and process technologies. These complex initiatives need complete and timely assessment techniques, with less attention on cost disadvantages. Therefore, performance indicators for this strategy should include the following:

(i) physical indicators;
(ii) economic indicators; and,
(iii) innovation-specific indices

In addition to the indices defined in Tables 2 and 3, the PMS should also include indicators concerned with product life, product green efficiency, and green image. Indicators defining product life show how long a product (or its components) can be used or reused.

Green image can be obtained from customers surveys aimed at finding out customer perception on a product. This evaluation is crucial for long-term forecasting of energy and materials usage. Table 4 presents a summary of innovation-based indicators.

No.	Indicator	Description
1	Product Life	Life cycle of different product components or sub-assemblies
2	Product green efficiency	Increase of green design features in a product; e.g., number of parts used, number materials used
3	Green image	Increase in customer goodwill due to greening activities

Table 4 - Innovation-based performance indicators

6.4 Measures for closed-loop strategies

Performance measures for closed-loop supply chains range from air emissions to energy recovery and recycling. Possible designs are: (i) physical indicators to describe environmental impact resulting from the remanufacturing activities; (ii) economic indices linked with economic efficiency; (iii) life-cycle analysis methods indicating the economic and physical impact of the supply chain throughout the product life cycle.

In a collaborative supply chain environment characterised by integrated relationships, innovative initiatives such as product take-back and take-back of recyclable end-of-life materials can easily be supported through involvement of suppliers. In this vein, life-cycle assessment is an appropriate model that should be implemented. This enables the organisation to measure the environmental impacts of the product over its entire lifecycle, right from collection of raw materials and design to recovery and/or disposal. The life cycle analysis model can be used to assess the impact of the industrial processes using: physical, economic, and social indicators. Hence, in addition to the compliance-based indicators (Table 2), the lead-based indicators (Table 3), and the innovation-based indicators (Table 4), the closed-loop strategy should include social/ecological performance indicators.

No.	Indicator	Description
1	Percent recycling	Increase in recycled material compared to material disposal
2	Percent remanufacture	Percentage increase in remanufactured products
3	Product green efficiency	Increase of green design features in a product; number of parts, etc
4	Green image	Increase in customer goodwill due to greening activities

Table 5 - Social/ecological performance indicators

Table 6 provides a list of suggested indicators for measuring social performance of a green supply chain. These indices include green image, a measure of the customers' perspective due to the firm's green practices such as product take back, recycling, remanufacturing and product recovery. Such activities have a positive impact on the firm's green image. Again, since green image and product life are qualitative, their values can be obtained via customer surveys.

7 CONCLUSTIONS

The framework suggested in this research provides platform or a guide for decision makers who intend to design an effective PMS for a specific GSCM strategy. The taxonomic approach and the measurement techniques provide operational guidelines for devising a set of performance indicators that are suitable for the selected green strategy. In this regard, the approach is applicable across various supply chain domains. In addition, the framework can be used to evaluate the possible available green options when changing from one green strategy to the other. For instance, when changing from compliance-centred to innovation-centred strategy, new indicators that pertain to the contribution of the enterprise's innovative product and process technologies should be designed.

Further research directions include the validation of the application of green performance measures for each PMS identified in this study. This will establish the validity of the measures and metrics for green supply chain performance measurement for different categories of green strategies. Furthermore, new comprehensive or hybrid indicators may be designed with regards to both environmental and economic performance.

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