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Fuzzy DEMATEL-based green supply chain management performance: application in cement industry

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# FUZZY DEMATEL-BASED GREEN SUPPLY CHAIN MANAGEMENT PERFORMANCE: APPLICATION IN CEMENT INDUSTRY


## Abstract

**Purpose** – Performance assessment of green supply chain management (GSCM) requires a systematic approach because of its interdisciplinary and multi-objective nature. The purpose of this paper is to propose a model to the performance assessment of GSCM.

**Design/methodology/approach** – A model is proposed, grounded on a literature review on GSCM performance, after which the causal relationships and prioritization of the sub-criteria are analyzed by fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) technique in a company operating in the cement industry.

**Findings** – An integrated holistic performance assessment model incorporating specifically the 6 criteria and 21 sub-criteria, is applied, which represents causal relationships and prioritization of sub-criteria.

**Research limitations/implications** – The proposed model can be generalized, because an integrative framework can be used in future empirical studies to analyze performance of GSCM. However, the causal relationships and prioritization among sub-criteria are analyzed based on the needs and capabilities of the individual company; therefore, the causal relationships found are company-specific.

**Practical implications** – The proposed model can be hired and implemented by companies striving for GSCM. This model allows companies to assess their current GSCM performance, analyze causal relationships, and prioritize sub-criteria.

**Originality/value** – Several studies have analyzed performance assessment in green supply chains; however, to the best of our knowledge, no study has taken an approach to performance assessment in GSCM that combines environmental, economics/financial, logistics, operational, organizational and marketing in the same framework. In addition, the cause-effect relationships identified will be the base for performance improvement.



**Key Words:** Green Supply Chain Management, Performance Assessment, Sustainability, Fuzzy DEMATEL, Cement Industry




## 1. Introduction

Increasing competition, and stricter regulations on the environment and public pressure are forcing companies to include environmental factors in their strategic planning and to establish corporate environmental strategy (Zhu et al., 2008). Green consciousness has evolved as a competitive advantage among firms since the late 1980s and early 1990s; while other motivating factors include economic benefits, concerns on legislation, pressures from stakeholders, corporate social responsibility and ethics. (Sarkis, 2003; Hervani et al., 2005). Companies have become aware of the importance of green issues in the supply chain in decreasing waste, increasing product quality and protecting natural resources for sustainability (Min and Kim, 2012).

As the companies focused on green initiatives, GSCM emerged as an important corporate strategy (Zhu and Sarkis, 2006), in order to obtain competitive advantage and to enhance customer satisfaction (McKinnon et al., 2015) as well as decreasing environmental impacts. Companies started to apply GSCM to increase market share and profit, to mitigate environmental risks, to improve responsiveness through flexibility in the range of products (Murray, 2000) and therefore to achieve competitive advantage (Lee et al., 2009).

Zhu and Sarkis (2006) state that GSCM can be considered as green purchasing and manufacturing, which covers green design, production, recycling in line with the green regulations. To achieve an effective GSCM, cooperation and collaboration among the GSCM partners is essential, particularly with suppliers and customers, where increase in profit and market share can be achieved and competitive advantage can be obtained.

According to Zhu et al. (2005), GSCM activities and practices are not single company-based activities, but rather depend on inter-organizational environmental management, incorporating industrial ecosystems, product life-cycle analysis, and increased manufacturer responsibility. Inter-organizational and cross-functional integration of environmental, production, engineering, marketing, and logistics personnel and their concerns are the characteristics of effective GSCM (Sarkis, 2006). GSCM integration has been associated with improved operational performance, such as lead time, productivity, and timely delivery (Chen et al., 2004).

The main aims of GSCM are to decrease cost, minimize resource use and pollution through green production, increase market share, improve brand image and enhance financial performance by improving environmental and social performance (Dawei et al., 2015). GSCM requires a significant enhancement in processes and products in order to satisfy the stricter regulations (Hsu and Hu, 2008). Therefore, green performance assessment became an important issue for all companies.

As a business target, sustainable development involves the attempt to balance economic, environmental and social performance (Jabbour and Jabbour, 2009; Lee et al., 2009). The main driver for “green” supply chain is to reduce cost and reach profitability (Srivastava and Srivastava, 2006).

The first contribution of this study is to identify the different dimensions of GSCM, including environmental, economic/financial, operational, logistics, organizational, and marketing performances. It also supports manufacturers in the understanding of the systematic and holistic assessment of GSCM performance through the identification of criteria, and sub-criteria. It can be said that, this contribution has two phases; (a) a theoretical holistic GSCM framework, and (b) an application-oriented GSCM framework through criteria, and sub-criteria.

The second contribution is the inclusion of the marketing dimension in GSCM performance evaluation. Liang and Chang (2008) indicated that the main effect of GSCM is to allow the development of green marketing. Therefore, it was necessary to add sub-criteria related to the marketing dimension, i.e., increasing customer satisfaction, marketing measures, and improving cooperation/collaboration with customers.

The aim of this study is to propose an overall GSCM performance assessment framework. In this paper, the established fuzzy DEMATEL method was applied to a new context. Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method was used in order to identify the importance and causal relationships between the sub-criteria and consequently, to create a structural model. Converting Fuzzy Data into Crisp Scores (CFCS) method was used to convert fuzzy judgments into crisp scores.

The remainder of the paper is structured as follows. The review of the literature on GSCM and GSCM performance items respectively are presented in Section 2. The proposed model presents criteria and sub-criteria of GSCM performance in Section 3. Fuzzy DEMATEL method is presented in Section 4. Section 5 describes the application of this study. Section 6 summarizes the implications, and finally, section 7, the conclusion, discusses possible future research directions.

## 2. Literature Review

Sustainability and green concepts have attracted increasing attention, leading to an expansion of green policies and standards to cover the whole supply chain (Khaksar et al., 2016). GSCM aims to decrease the life cycle environmental impact of a product by integrating the following processes and targets: design, use and allocation of resources, reuse, recycling, and minimizing the production and use of harmful materials (Diabat et al., 2013).

Performance assessment is critical to designing, planning, implementing and monitoring the company performance. It is regarded as a tool to assess the effectiveness and efficiency of the management and even to make comparisons between companies.

GSCM performance measurement can be conducted by both quantitative and qualitative methods. The measurements can be categorized under several sub-groups such as financial measurements including the increase of profitability, market share, revenue, and return on investment; and operational measures including customer service level, and inventory turnover. The measurement method can be unique to the company, or to the department of the company, based on the objectives. Operations research techniques like simulation or mathematical models have been rarely applied; however, Srivastava (2007) and McKinnon et al. (2015) stated that mathematical and statistical methods can be used in GSCM performance measurement. DEMATEL method was preferred by Wu et al. (2010), Lin et al. (2011), Lin (2013), and Govindan et al. (2015a). Wu et al. (2010) explored the relationships between knowledge transfer and GSCM performance using fuzzy DEMATEL method. Lin et al. (2011) found the causal relationships between the criteria in developing green performance of the manufacturing companies. Lin (2013) explored the effecting factors among eight criteria of GSCM practices, performances, and external pressures. Govindan et al. (2015a) figured out the GSCM practices for enhancing economic and environmental performance. These models were used to determine the cause and effect relationships among the GSCM variables. In the literature, the most studied topics within GSCM were revealed as environmental issues, company practices, process management, and sustainability (Malviya and Kant, 2015).

Olsthoorn et al. (2001) argued that the interaction between company and the environment should be the base for green performance assessment, whereas Wagner and Schaltegger (2004) suggested measures including water and energy usage, use of toxic materials, non-renewable resources, emissions, noise, smell, damage to landscape and accidents.

Malviya and Kant (2015) noted that GSCM literature mainly focuses on the sub-topics such as supplier selection, design, purchasing, quality, performance measurement, waste management.

According to Zhu and Sarkis (2004), and Rao and Holt (2005), GSCM focuses on improving environmental and financial performance, encompassing a wide range of aspects from environmental management to green design.

Gandhi and Sharma (2014) described the literature on GSCM practices and performance. Hervani et al. (2005) suggested the need for performance measurement systems to include external & internal reporting and control. Wagner and Schaltegger (2004), and Rao and Holt (2005) explained green performance as minimizing impacts on the environment by increasing cooperation and collaboration, integrating managerial and green concerns, which would eventually improve corporate image and marketing, thus achieving competitive advantage.

Vachon and Klassen (2007) considered that environmental alignment and cooperation may support manufacturing and GSCM performance. As the collaboration and coordination in the supply chain increases, financial and organizational performance will improve (da Silveira and Arkader, 2007). Therefore, cooperation, collaboration and integration with green suppliers in GSCM are the key to economic and environmental performance improvement.

Zhu et al. (2008) proposed various scales to measure GSCM in terms of continuous improvement, implementation and benchmarking. Green et al. (2012) emphasized that within GSCM, environmental performance should focus on decreasing pollutant levels, while economic performance should focus on reduction of energy costs. Zhu et al. (2008) underlined the close relation between economic performance and environmental measures. Zhu et al. (2013) highlighted the mediation effects, and the need to take a holistic view, integrating internal and external GSCM activities. In addition, improving environmental performance will enable companies to enhance the corporate image, which will, in turn, bring higher sales and profits.

## 3. Proposed Model

Since a holistic approach is required to determine future plans, GSCM studies focusing on green performance are based on the areas of logistics, manufacturing and operations and environmental performance. Many studies emphasize the need to define the sustainable measures, and the difficulty associated with defining and accurately measuring these to assess the green performance (Hervani et al. 2005; McKinnon et al. 2015).

The need therefore arises for a holistic model that can incorporate and integrate tangible and intangible criteria related with environmental, economic, logistics, operational, organizational and marketing concepts. This study is unique in that it attempts to create such a model, within an industry-specific context, based on criteria and sub-criteria.

Also, there is a need for a marketing criterion in overall GSCM performance assessment framework, lacking in the previous literature. Previous research on GSCM focused on especially environmental, economic and operational performance, and also general corporate performance; green marketing was not considered in GSCM performance assessment. However; according to Hervani et al. (2005), as well as green purchasing, green manufacturing, and reverse logistics, GSCM also includes green distribution/marketing. Green purchasing, green manufacturing, green packaging, green distribution and marketing are all a part of GSCM (Luthra et al., 2011).

### *3.1. Environmental Performance*

The environmental performance measures focus on reducing supply chain operations' production of carbon dioxide, solid and effluent wastes, emissions to air and water, sulfur dioxide ($SO_2$), nitrogen oxide (NO), energy consumption, use of water and fuel, water pollution, air pollution, hazardous and toxic material use and consumption, and gas emissions

(Zhu et al., 2008). Aronsson and Brodin (2006) revealed that emission measurement is one of the crucial measures for environmental impact assessment.

Green packaging, distribution, and reverse logistics are key factors in environmental performance in the supply chain. More efficient suppliers' processes may contribute to decrease transaction costs, wastes, hazardous materials, increasing recycling and reuse of raw materials and to follow environmental regulations (Sarkis, 2003).

### *3.2. Economic/Financial Performance*

Economic and financial performance is linked to decreased costs, increased profits and reduction of environment-damaging activities such as material purchase, energy consumption, discharge and treatment of waste and occurrences of accidents (Zhu et al., 2008).

There are several studies which measure economic performance based on the reduction in costs as an outcome of green activities (Zhu et al., 2005), whereas Rao (2002) suggested profit or sales as indicators. The results of these studies highlighted the relationship between a company's environmental management and economic performance.

### *3.3. Logistics Performance*

Green logistics is an environmentally-friendly and effective transportation mode, in contrast to conventional road and air transport, which have hazardous effects on environment due to consuming fossil fuels, in turn, producing $CO_2$, and polluting the air, soil and water (Min and Kim, 2012). The implementation of logistics should be harmonized with green production, marketing, consumption and other economic activities (Hang, 1996). Green procurement, green material/component management and production, green distribution, green marketing, and reverse logistics are some activities included in green logistics (Hervani et al., 2005). Green logistics also have a positive effect on processes such as purchasing, packaging and transportation. Rao and Holt (2005) underlined the positive influence of outbound logistics, and cost savings on competitiveness with respect to improved quality, productivity, efficiency, and cost saving.

### *3.4. Operational Performance*

Zhu et al. (2008) defined operational performance as the ability of a company to satisfy their customers by an efficient production and high quality in delivery, while reducing defects and inventory levels. Customer satisfaction, flexibility of suppliers and interaction with these companies, and internal service quality are the three most important criteria for companies aiming to improve operational performance (Wu et al., 2010).

By developing the operational performance, organizations gain an advantage which increases the degree of organizational environmental awareness. The key activities that are necessary to improve operational performance are organizational internal GSCM practices including the integration of environmental management systems and staff involvement, and activities such as recycling and reuse (Carter and Carter, 1998). Benefits of producing environmentally-friendly products are not only limited to safety and lower prices, but also include increased and more consistent quality level, and greater scrap values (Sarkis, 2001). Furthermore, by reducing energy consumption, and waste discharge and treatment fees, eco-design products result in savings. Even though these kinds of products have significantly positive effects on environmental performance (Zhu et al., 2005), they have less significant effect on economic performance (Lewis and Gretsakis, 2001). Moreover, green products include green materials, designs, manufacturing appropriate materials, and packaging to reduce resources, hazardous emission, environmental pollution (Lee et al., 2009).

*3.5. Organizational Performance*

Organizational performance is a measure designed to evaluate the company's level of success in achieving its goals (Daft, 1995). Companies use GSCM concepts which integrate organizational and environmental performances (Zhu and Cote, 2004). In order to minimize environmental risks, GSCM incorporates an important organizational performance indicator.

In order to transform activities and processes to "green", GSCM requires the employment of internal environmental management. This kind of management leads better organizational performance. To achieve this goal, top management and operational personnel must cooperate. While top management is responsible for providing strategic and organizational performance measurement, and maximizing shareholder wealth, operational personnel should be trained to gather and evaluate data (Hamel and Prahalad, 1989). Moreover, Chien (2014) noted that, organizational performance includes social performance, which stipulates that an organization should provide a healthy work environment, show social commitment and participation, offer education and training, and engage in human resources development.

*3.6. Marketing Performance*

Evaluation of the association between marketing practices/activities and corporate performance refers to marketing performance measurement (Clark and Ambler, 2001). Marketing performance is an organization's ability to improve its sales and market share relative to competitors. The marketing performance measurement is defined by Green et al. (1995) as being the level of market success achieved by at the maturity stage of the market. Other indicators of the performance are revenue, sales volume, return on investment (ROI), and return on satisfaction (ROS), customer satisfaction and loyalty, purchase intention, and the level of quality. According to Ambler and Kokkinaki (1997), the ley indicators are increase in sales and market share, the contribution of profit, and customer preference/purchase intention.

According to Zampese et al. (2016), green marketing is based on marketing performance, including activities such as branding, growth in sales, market share customer satisfaction and loyalty. GSCM execution means finding a balance in the relation between marketing performance and environmental issues. In order to fulfill the customer needs, companies need to pay attention to sustainable environmental solutions in their processes (Zhu and Sarkis, 2006).

Table 1 shows the detailed criteria set, in other words, the model, which includes the main criteria, sub-criteria, and the measurements.

[TABLE 1 NEAR HERE]

## 4. Methodology

Decision Making Trial and Evaluation Laboratory (DEMATEL) method measures the cause-effect relationships between criteria. In this study, we applied fuzzy DEMATEL method in order to construct a cause-effect model for the performance of the GSCM.

*4.1. Fuzzy Sets Theory*

Decision-makers experience uncertainties in the decision-making process due to the subjective manner of their judgments. To deal with this subjectivity and vagueness in human judgment, Zadeh (1965) introduced fuzzy set theory to demonstrate the linguistic terms used when dealing with a decision process. In the theory, mathematical operators and programming are also allowed to apply to the fuzzy domain. A class of objects with a continuum of grades of membership is called a fuzzy set. Characteristic function is used to assign a grade of membership (from zero to 1) to each object and this grade characterizes fuzzy sets. If a fuzzy set is represented by a symbol, then a tilde "~" is placed above the symbol (Zadeh, 1965).

There are various fuzzy membership functions. In this paper, we use triangular fuzzy numbers. A triangular fuzzy number (TFN), $\tilde{M}$ , is shown in Figure 1.

[FIGURE 1 NEAR HERE]

A triangular fuzzy number is indicated as ($l_{ij}$, $m_{ij}$, $r_{ij}$). The parameters $l_{ij}$, $m_{ij}$, $r_{ij}$, respectively refer the smallest possible, the most promising, and the largest possible values that characterize a fuzzy event.

*4.2. Fuzzy DEMATEL*

Decision Making Trial and Evaluation Laboratory (DEMATEL) method measures the cause-effect relationships between complicated criteria in order to allow the construction and analysis of a structural model. The procedures involved in the fuzzy DEMATEL method will be discussed in the following sections.

*4.2.1. DEMATEL Method*

The DEMATEL method originated from The Battelle Memorial Institute aiming to search for integrated solutions (Gabus and Fontela, 1972; Gabus and Fontela, 1973). The popularity of the method is due to the fact that it allows the complex structure of cause-effect relationships to be easily envisioned (Lin and Wu, 2008).

The structure of DEMATEL method is subject to matrices or digraphs, which are able to distinguish the complicated criteria into cause and effect groups, and manage the inner dependencies. Digraphs are able to indicate the directed relationships of sub-systems; therefore, they are superior to directionless graphs. A digraph may reflect a network, or a dominated relationship between criteria (Wu and Lee, 2007).

The matrices or digraphs represent the relations between the criteria, in which the numerical expressions show the strength of the influence. According to the fundamental principles of the DEMATEL method, the system consists of a set of criteria, that is, C = {$C_1$, $C_2$, …, $C_n$}, and the pairwise comparisons are used to show the mathematical relations. Hence, the DEMATEL method shows the cause-effect relationships between the complicated criteria in a logical way.

The solution steps are as follows:

**Definition 1:** The measurement scale for pairwise comparisons were designed as four levels, 0 (no influence), 1 (low influence), 2 (high influence), and 3 (very high influence).

**Definition 2:** The direct relation matrix, Z, is an $n \times n$ matrix acquired from pairwise comparisons based on relationships and influences between a set of criteria. $z_{ij}$ symbolizes the degree of the effect of criterion *i* to criterion *j*, i.e. $Z = \lfloor z_{ij} \rfloor_{n \times n}$.

**Definition 3:** The normalized direct relation matrix, X, i.e., $X = \lfloor x_{ij} \rfloor_{n \times n}$, and 0 ≤ $x_{ij}$ ≤ 1, is attained by way of the formulas (1) and (2).

$$X = s \cdot Z \tag{1}$$

$$s = \frac{1}{\max_{1 \le i \le n} \sum_{j=1}^{n} z_{ij}}, i, j = 1, 2, \cdots, n. \tag{2}$$

**Definition 4:** The total relation matrix, T, is obtained by the formula (3), in which I represent the identity matrix.

$$T = X(I - X)^{-1}. \tag{3}$$

**Definition 5:** The row totals and the column totals of the total relation matrix, T, are represented as D and R by the formulas (4)-(6).

$$T = t_{ij}, \quad i,j = 1,2,\dots,n, \tag{4}$$

$$D = \sum_{j=1}^{n} t_{ij}, \tag{5}$$

$$R = \sum_{i=1}^{n} t_{ij}, \tag{6}$$

where D and R represents the row totals and the column totals, respectively.

**Definition 6:** A cause-effect diagram can be obtained by graphing the dataset, in which the (D+R) represents the horizontal axis, and is comprised of summing up D with R, and (D-R) represents the vertical axis, and is comprised of subtracting R from D.

In order to convert the fuzzy data into crisp scores, Converting Fuzzy Data into Crisp Scores (CFCS) defuzzification technique is used.

*4.2.2. Converting Fuzzy Data into Crisp Scores (CFCS)*

The various defuzzification techniques may be divided into two categories: vertical or horizontal representation of possibility distribution (Oussalah, 2002). However, Opricovic and Tzeng (2003) stated that a good defuzzification technique should take into consideration all main characteristics of the fuzzy number, i.e., shape, height, spread, and the relative location of x axis.

The most popular defuzzification technique is the Centroid (Center-of-gravity) method (Yager and Filev, 1994); however, this method cannot make a distinction between the same crisp-valued fuzzy numbers, even though they have different shapes Therefore, Converting Fuzzy data into Crisp Scores (CFCS) defuzzification technique is widely adopted, producing more accurate crisp scores compared to the Centroid method (Wu and Lee, 2007).

The CFCS method was proposed by Opricovic and Tzeng (2003), and its procedure is subject to identifying the left and right scores by fuzzy minimum and fuzzy maximum. The total score is identified by taking a weighted average in accordance with the membership functions. Let $\tilde{z}_{ij}^{k} = (l_{ij}^{k}, m_{ij}^{k}, r_{ij}^{k})$ states the fuzzy judgments of the evaluator $k$ (k = 1,2,. . . ,p) about the level of the influence of criterion $i$ to criterion $j$. Five-step algorithm is expressed as follows (Opricovic and Tzeng, 2003):

(1) Normalization:

$$xl_{ij}^{k} = (l_{ij}^{k} - \min l_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{7}$$

$$xm_{ij}^{k} = (m_{ij}^{k} - \min l_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{8}$$

$$xr_{ij}^{k} = (r_{ij}^{k} - \min l_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{9}$$

where $\Delta_{\min}^{\max} = \max r_{ij}^{k} - \min l_{ij}^{k}$.

(2) Calculate left and right normalized values:

$$xls_{ij}^{k} = xm_{ij}^{k} / (1 + xm_{ij}^{k} - xl_{ij}^{k}), \tag{10}$$

$$xrs_{ij}^{k} = xr_{ij}^{k} / (1 + xr_{ij}^{k} - xm_{ij}^{k}). \tag{11}$$

(3) Calculate total normalized crisp value:

$$x_{ij}^{k} = \left[ xls_{ij}^{k}(1 - xls_{ij}^{k}) + xrs_{ij}^{k} xrs_{ij}^{k} \right] / \left[ 1 - xls_{ij}^{k} + xrs_{ij}^{k} \right] \tag{12}$$

(4) Calculate crisp values:

$$z_{ij}^{k} = \min l_{ij}^{k} + x_{ij}^{k} \Delta_{\min}^{\max}. \tag{13}$$

(5) Integrate crisp values:

$$z_{ij}^{k} = \frac{1}{p}(z_{ij}^{1} + z_{ij}^{2} + \cdots + z_{ij}^{p}). \tag{14}$$

*4.2.3. The Procedure of Fuzzy DEMATEL Method*

Under a fuzzy environment, the analytical procedure of the proposed method is described as follows:

*Step 1: Identifying the decision goal and forming a committee*: Decision-making process involves the following steps: (1) describing the decision goals, (2) collecting the relevant data, (3) identifying the possible alternatives, (4) assessing the alternatives with regard to their advantages and disadvantages, (5) selecting the best alternative, and (6) monitoring the results whether the decision goals are attained or not (Opricovic and Tzeng, 2004). For this reason, the decision-making process starts with the determination and description of the decision goals. Another important requirement is to constitute a committee to collect the group knowledge that is need for problem solving (Wu and Lee, 2007).

*Step 2: Developing evaluation criteria and designing the fuzzy linguistic scale:* Due to the nature of cause-effect relationships of the criteria, they involve many complex aspects. The DEMATEL method should be used to create a structural model in order to divide the significant criteria into cause group and effect group. To deal with the subjectivity and vagueness of human judgment, the degree of influence of each criterion over others is expressed by one of five linguistic terms: No Influence (No), Very Low Influence (VL), Low Influence (L), High Influence (H), and Very High Influence (VH). These linguistic terms are described in positive triangular fuzzy numbers ($l_{ij}$, $m_{ij}$, $r_{ij}$) as shown in Table 2.

[TABLE 2 NEAR HERE]

*Step 3: Acquiring and aggregating the assessments of decision makers:* A group of experts are asked to evaluate the influences of criteria to each other in order to measure the relationships between all criteria, that is, C = {$C_1$, $C_2$, …, $C_n$}. These fuzzy evaluations are then defuzzified into crisp values, $z_{ij}$, by CFCS method. As a consequence, the direct relation matrix, $Z = \lfloor z_{ij} \rfloor_{nxn}$, is acquired by the formulas (7)-(14) (Lin and Wu, 2008).

*Step 4: Establishing and analyzing the structural model:* After gathering the direct relation matrix, Z, by the formulas (1) and (2), the normalized direct relation matrix, X, can be acquired. The total relation matrix, T can then be obtained by the formula (3). The row totals and the column totals of the total relation matrix, T, are represented as *D* and *R* by the formulas (4)-(6). A cause-effect diagram can be obtained by graphing the dataset, in which the (*D*+*R*) represents the horizontal axis, and is comprised of summing up *D* with *R*, and (*D*-*R*) represents the vertical axis, and is comprised of subtracting *R* from *D*. (*D*+*R*) and (*D*-*R*) are called "Prominence", and "Relation", respectively. Prominence represents the degree of importance of the criterion, and the Relation distinguishes the criteria as the cause or effect criteria. If the (*D*-*R*) is positive, the criterion falls into the cause group, and if negative, into the effect group. Hence, the cause-effect diagrams clarify the complex relationships among a set of criteria, and enable the visualization of the structural model. Appropriate decisions could be reached by determining the cause group and effect group, and distinguishing the differences between cause criteria and the effect criteria, based on the cause-effect diagrams (Wu and Lee, 2007).

## 5. Application

The application was conducted with a leading cement manufacturing firm located in Bornova, Izmir, Turkey. Diabat et al. (2013) suggested that the framework developed in their study may be applicable to potentially environmentally-harmful industries such as cement manufacturing. The reason for selecting this company is the relative importance of its carbon footprint, and its need for effective waste management. This company is engaged in some responsible production and consumption business projects, such as energy efficiency project in production process, rehabilitation work on the site of terminated mining activity, and solar energy usage projects.

Cement plants are the highest emitters of carbon dioxide of any industries in the world (Benhelal et al., 2012). According to Benhelal et al. (2012), every ton of cement production leads to the emission of around 900 kg of $CO_2$ constituting approximately 5-7 % of all global carbon dioxide emission (Chen et al., 2015). The cement industry is currently focusing on its energy intensive operations, due to the growing importance of environmental and sustainability issues. Cement manufacturers consume large amounts of non-renewable raw materials and produce major amounts of carbon dioxide (Potgieter, 2012); therefore, emphasize the need to reduce, re-use, and recycle to ensure the lowest possible emissions. The carbon footprint is the measure of damage caused by human activities to the environment in terms of the amount of greenhouse gas as measured by unit carbon dioxide. Carbon footprint consists of two main parts: the direct/primary footprint, and the indirect/secondary footprint. In fulfilling their responsibilities, respect for nature, and avoiding excessive environmental pollution are the companies' guiding principles. There is growing awareness that protecting and improving the environment is an integral part of work and life. The Cement Sustainability Manufacturing Program (CMS) aims "to balance society's need for cement products with stewardship of the air, land, and water, conservation of energy and natural resources, and maintenance of safe work places and communities". (http://www.cement.org/concrete-basics/manufacturing/cement-industry-sustainability-manufacturing-program). Control of emission of greenhouse gases are based on strict government regulations and the Paris Agreement on Climate Change. These regulations created increasing pressure on cement factories to modify their business strategies and production process. Therefore, the company is making maximum effort to prevent environmental pollution, and use natural sources. They are acting to reduce wastes at source, and return wastes to the economy wherever possible.

In addition, the company has strictly controlled all hazardous and solid wastes through its Waste Management System, implemented since July 2005 in compliance with legal requirements. In addition, the company burns all dangerous and solid wastes for energy production and disposes of the remains.

In data collection process, five experts carried out pairwise comparisons; the deputy general manager, the plant manager, the purchasing manager, the production manager, and the human resources manager. The pairwise comparisons were made by the authorities responsible for green activities with the consent of the Board of Directors.

Hervani et al. (2005) pointed out that there is no perfect tool for traditional performance measurement systems, and that their usage is greatly dependent on acceptance by organizations. In other words, there is no single generally applicable approach for generalizing the performance measurements, because the scales and the applications are usually specific to the organizations. Therefore, although the proposed model may be generalized, the results of the application are unique to each company.

Table 3 shows the pairwise comparison matrix of one expert. Table 4 shows the total relation matrix; T. Total relation matrix is found using the formula (3).

D and R values are found using the formulas (4)-(6). According to the results, the cause-effect diagram is occurred as seen in Figure 2.

[TABLE 3 NEAR HERE]

[TABLE 4 NEAR HERE]

[FIGURE 2 NEAR HERE]

According to the result of fuzzy DEMATEL causal diagram;

1) The Cause Group consists of Revenues (C5), Increase in Quality (C8), Increasing Efficiency (C9), Improving Green Manufacturing (C10), Improving Green Packaging (C11), Improving Green/Eco Design (C12), Improving Green Logistics (C13), Improving Reverse

Logistics (C14), Improving Green Purchasing (C15), Green Information Systems (C18), and Improving Cooperation/Collaboration with Customers (C20).

2) The Effect Group consists of Decreasing Emissions (C1), Decreasing Energy Consumption (C2), Decreasing Business Waste (C3), Decreasing Environmental Cost (C4), Cost-Oriented (C6), Revenue-Oriented (C7), Improving Green Image (C16), Incorporating Environmental Management (C17), Increasing Customer Satisfaction (C19), and Marketing Measures (C21).

To achieve high performance from the effect group factors, it is important to monitor and deal with the cause group factors, because this group refers to the influencing factors, while the effect group refers to the influenced factors (Fontela and Gabus, 1976). Within this context, Improving Green Manufacturing (C10) is the most important factor, because it has the most significant relation among all factors. Incorporating Environmental Management (C17) is second, and Improving Green/Eco Design (C12) is third. Increasing Efficiency (C9) is the most influencing factor, at the highest level of the Cause Group, and Improving Green Image (C16) is the most influenced factor, at the lowest level of Effect Group.



## 6. Implications

In this study, fuzzy DEMATEL method was employed to analyze and assess the relationships between the sub-criteria in terms of GSCM performance in cement industry. 21 sub-criteria were evaluated using pairwise comparisons, and some implications were obtained in order to determine the key sub-criteria.

Firstly, the results of fuzzy DEMATEL method were taken into consideration as the basis for defining the importance levels of the factors. Within this context, our investigation illustrated that improving green manufacturing is found to be the most important factor, in line with Chen et al. (2006), who argued that green manufacturing process and green products have a positive relationship with competitive advantage. Incorporating environmental management was found to be the second most important factor, in line with the findings of Carter and Carter (1998), who highlighted the key role of internal environmental management in improving enterprises' performance. Interior policies and action plans of environmental management system directly affect the organization as a whole (Coglianese and Nash, 2001). Improving Green/Eco Design was found to be the third most important factor, supporting the views of Chen et al. (2006), who stated that eco design and green products were just as important as green innovation in increasing production system efficiency.

Secondly, the results of fuzzy DEMATEL method were taken into consideration as the basis for the cause group. Within this context, efficiency was found to be the most influencing factor, supporting Liang and Chang's (2008) findings that GSCM helps companies improve environmental performance, minimize waste, and attain cost savings through promoting efficiency. Green purchasing was found to be the second most influencing factor, following the consensus in the literature. According to Follows and Jobber (2000), marketing managers are being pressured by environmentally-aware consumers to adopt a more environmental-protection focused purchasing strategy. In line with Liang and Chang (2008), who stated that green purchasing, green manufacturing, and green marketing activities lead to improved GSCM performance, our investigation illustrated that green logistics was found to be the third most influencing factor. Similarly, Diabat et al. (2013) proposed that it was important for design, manufacturing, packaging, and delivery to conform to the environmental objectives for better GSCM performance.

Finally, the results of fuzzy DEMATEL method were taken into consideration as the basis for the effect group. Our investigation illustrated that improving green image was found to be the most influenced factor, in line with the results of Lin et al. (2011), and Diabat et al. (2013). These studies indicated that GSCM can enhance corporate image on the market, and thus maintain competitiveness. Increasing customer satisfaction was found to be the second most influenced factor, agreeing with Azevedo et al. (2011), who pointed out the positive effect of customer satisfaction on GSCM performance. Environmental collaboration with customers increases the level of customer satisfaction through providing the reliability of operations (Lee et al., 2007). Marketing measures was found to be the third most influenced factor, in line with Zampese et al. (2016), who emphasized the close relationship between green marketing and performance, as also argued by Fraj et al. (2011). Many of the studies for GSCM deal with the corporate performance, and therefore, aim to show a relationship between enterprises' GSCM activities and the financial position, and even competitive advantage.

The relation between efficiency and manufacturing also deserves attention in GSCM. Improving Green Manufacturing (C10) is the most important factor, whereas Increasing Efficiency (C9) is the most influencing; therefore, it is possible to say the higher the green manufacturing measurement scores, the greater the improvements seen in the measurements of the efficiency factor.

## 7. Conclusion

There are various reasons for assessing the performance of companies' processes. Due to the increasing competition, and stricter environmental regulations and public pressure, the companies have been forced to assess environmental performance in order to establish corporate environmental strategy (Zhu et al., 2008). Despite the large number of studies in GSCM implementation, there is a lack of overall understanding of theoretical and methodological dimensions (Malviya and Kant, 2015). To address this deficiency, an innovative holistic GSCM performance assessment model is proposed in this paper.

The main contribution of this study is to reveal the different dimensions of GSCM such as environmental, economic/financial, operational, logistics, organizational, and marketing performances. It also supports manufacturers in the understanding of the systematic and holistic assessment of GSCM performance through criteria, and sub-criteria. In this paper, fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method was used in order to identify the importance and causal relationships between the sub-criteria and consequently, to create a structural model.

The second main contribution is the inclusion of the marketing dimension in GSCM performance evaluation. Liang and Chang (2008) indicated that the main effect of GSCM is the development of green marketing. Therefore, it was necessary to add sub-criteria for the marketing dimension, i.e., increasing customer satisfaction, marketing measures, and improving cooperation/collaboration with customers.

Therefore, the discussed case of cement industry is potentially of great value for improving the company's GSCM performance, and guiding managers to work on issues in GSCM. The results can enable the cement company to assess their own performance.

The limitation of this research is that, as with all MCDM applications, the research includes subjective judgments. In their study employing DEMATEL, Govindan et al. (2015a) stated that although the model utilized is able to take into consideration the ambiguities, it is not possible to generalize the results.

Further possible research could focus on finding the sub-criteria weights, identifying the respective measurements and finding their weights, and proposing an overall performance score framework for the company in order to determine a road map.

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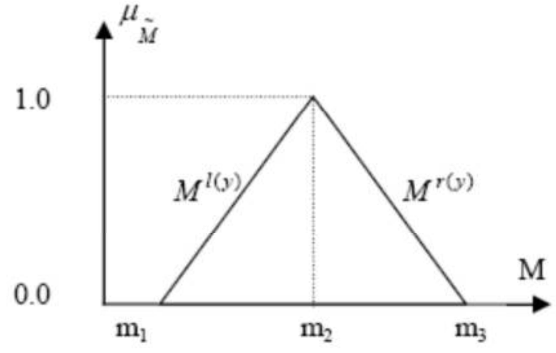


**Figure 1: A triangular fuzzy number**


C18
C8
0
10
11
12
C3
C2
C7
-0.5
C4
-1
C21
-1.5
C19
-2

## Table 1: Evaluation of Main Criteria and Sub-Criteria for GSCM Performance

| MAIN CRITERIA | SUB-CRITERIA | REFERENCES |
|---|---|---|
| **Environmental Performance**<br><br>Zhu and Sarkis (2004); Zhu et al. (2008); Diabat et al. (2013); Govindan et al.(2015a); Wu et al (2015) | Decreasing Emissions | Govindan et al.(2015a) |
| | Decreasing Energy Consumption | Zhu et al. (2005); Zhu et al. (2007); Zhu et al. (2008) |
| | Decreasing Business Waste | Zhu et al. (2007); Zhu et al. (2008) |
| | Decreasing Environmental Cost | Zhu et al. (2007); Zhu et al. (2008) |
| | Increasing Environmental Revenues | Azevedo et al. (2011); Govindan and Popiuc (2014) |
| **Economic / Financial Performance**<br><br>Hervani et al. (2005); Zhu et al. (2008); Lin et al. (2014); Wu et al. (2015) | Cost Oriented | Chuang (2014) |
| | Revenue Oriented | Hervani, et al. (2005); Duarte, et al. (2011); Laosirihongthong et al. (2013) |
| **Operational Performance**<br><br>Zhu et al. (2008); Wu et al. (2015) | Increase in Quality | Azevedo et al. (2011); Zhu et al. (2008); Diabat et al. (2013); Zhu et al. (2013) |
| | Increasing Efficiency | Azevedo et al. (2011); Duarte et al. (2011) |
| | Improving Green Manufacturing | Chuang (2014) |
| | Improving Green Packaging | Zhu et al. (2007); Diabat et al. (2013) |
| | Improving Green/Eco Design | Zhu et al. (2005); Zhu et al. (2007); Zhu et al. (2008); Zhu and Sarkis (2006); Lin (2013); Lin et al. (2014); Wu et al. (2015) |
| **Logistics Performance**<br>McKinnon et al. (2015) | Improving Green Logistics | Malviya and Kant (2015) |
| | Improving Reverse Logistics | Govindan et al. (2015b) |
| | Improving Green Purchasing | Zhu and Geng (2001); Zhu et al. (2008); Wu et al.(2015) |
| **Organizational Performance**<br>Zhu et al. (2008) | Improving Green Image | Zhu et al. (2007); Azevedo et al. (2011) |
| | Incorporating Environmental Management | Zhu et al. (2008); Govindan et al.(2015a) |
| | Green Information Systems | Green et al.(2012) |
| **Marketing Performance**<br>Zhu and Cote (2004) | Increasing Customer Satisfaction | Hervani et al. (2005); Azevedo et al. (2011); Wu et al.(2015) |
| | Improving Cooperation/Collaboration with Customers | Zhu et al. (2008); Lin et al. (2014); Wu et al. (2015) |
| | Marketing Measures | Duarte et al. (2011) |

**Table 2: Fuzzy Linguistic Scale**

| Linguistic terms | Triangular fuzzy numbers |
|---|---|
| Very high influence (VH) | (0.75,1.0,1.0) |
| High influence (H) | (0.5,0.75,1.0) |
| Low influence (L) | (0.25,0.5,0.75) |
| Very low influence (VL) | (0,0.25,0.5) |
| No influence (No) | (0,0,0.25) |

**Table 3: Pairwise Comparison Matrix of one of the Experts**

**EXPERT 1**

| | | ENVIRONMENTAL PERFORMANCE | | | | | ECONOMIC/FINANCIAL PERFORMANCE | | OPERATIONAL PERFORMANCE | | | | | LOGISTICS PERFORMANCE | | | ORGANIZATIONAL PERFORMANCE | | | MARKETING PERFORMANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Decreasing Emissions | Decreasing Energy Consumption | Decreasing Business Waste | Decreasing Environmental Cost | Revenues | Cost-Oriented | Revenue-Oriented | Increase in Quality | Increasing Efficiency | Improving Green Manufacturing | Improving Green Packaging | Improving Green/Eco Design | Improving Green Logistics | Improving Reverse Logistics | Improving Green Purchasing | Improving Green Image | Incorporating Environmental Management | Green information systems | Increasing Customer Satisfaction | Improving Cooperation/Collaboration with Customers | Marketing Measures |
| ENVIRONMENTAL PERFORMANCE | Decreasing Emissions | NO | VH | NO | NO | VH | VH | L | VL | L | L | NO | NO | NO | L | L | NO | L | VL | NO | NO | NO |
| | Decreasing Energy Consumption | VH | NO | L | VL | L | VH | H | NO | H | L | NO | NO | NO | NO | NO | L | L | VL | NO | NO | NO |
| | Decreasing Business Waste | H | L | NO | L | L | VL | VL | VL | VL | VL | NO | NO | NO | NO | NO | L | L | VL | NO | NO | NO |
| | Decreasing Environmental Cost | NO | NO | VL | NO | VL | L | L | VL | VL | VL | NO | NO | NO | NO | NO | L | VL | NO | NO | NO | NO |
| | Revenues | VH | VH | H | L | NO | H | H | L | L | NO | NO | NO | NO | NO | NO | H | H | H | NO | NO | NO |
| ECONOMIC/FINANCIAL PERFORMANCE | Cost-Oriented | NO | L | L | NO | NO | NO | VH | NO | VH | NO | NO | VL | NO | VL | VL | NO | NO | VL | NO | NO | NO |
| | Revenue-Oriented | NO | L | H | NO | NO | VL | NO | VL | VH | NO | NO | NO | NO | VL | NO | NO | NO | NO | NO | NO | NO |
| OPERATIONAL PERFORMANCE | Increase in Quality | NO | NO | NO | NO | NO | H | H | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | H | H | L |
| | Increasing Efficiency | L | H | NO | VH | VH | H | H | VL | NO | NO | NO | NO | NO | NO | NO | NO | L | VL | NO | NO | NO |
| | Improving Green Manufacturing | VH | H | VH | H | H | VL | VL | VL | L | NO | VL | NO | NO | NO | NO | VH | VL | VL | VL | VL | VL |
| | Improving Green Packaging | L | L | H | VL | VL | VL | VL | NO | NO | VH | NO | VH | L | VL | VL | VH | VL | NO | VL | VL | VL |
| | Improving Green/Eco Design | L | L | L | VL | VL | VL | VL | NO | NO | H | VH | NO | VL | VL | L | VH | H | NO | NO | VL | L |
| LOGISTICS PERFORMANCE | Improving Green Logistics | VH | H | H | VL | L | VL | NO | NO | NO | VH | VL | VL | NO | H | VH | H | H | VL | NO | NO | NO |
| | Improving Reverse Logistics | L | L | H | L | L | VL | VL | NO | L | VH | VL | VL | VH | NO | VH | H | H | VL | NO | NO | NO |
| | Improving Green Purchasing | H | L | VL | L | VL | NO | VL | NO | VL | H | H | VL | VH | H | NO | H | VL | VL | NO | NO | NO |
| ORGANIZATIONAL PERFORMANCE | Improving Green Image | L | VL | L | VL | VL | NO | NO | NO | VL | H | VL | VL | NO | L | L | NO | H | L | VL | VL | VL |
| | Incorporating environmental management | L | VL | L | VL | L | NO | VL | NO | NO | H | VL | L | L | L | L | H | NO | H | NO | NO | NO |
| | Green information systems | VL | VL | VL | VL | VL | NO | VL | NO | NO | L | VL | L | VL | VL | VL | VL | L | NO | NO | NO | NO |
| MARKETING PERFORMANCE | Increasing Customer Satisfaction | NO | NO | NO | NO | NO | H | L | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Improving Cooperation/Collaboration with Customers | NO | NO | NO | NO | NO | NO | VH | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | VH | NO | VH |
| | Marketing Measures | NO | NO | NO | NO | NO | NO | VL | NO | NO | NO | NO | NO | NO | NO | NO | VL | NO | NO | L | L | NO |

# Table 4: Total Relation Matrix, T

| T | | ENVIRONMENTAL PERFORMANCE | | | | | ECONOMIC/FINANCIAL PERFORMANCE | | OPERATIONAL PERFORMANCE | | | | | LOGISTICS PERFORMANCE | | | ORGANIZATIONAL PERFORMANCE | | | MARKETING PERFORMANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Decreasing Emissions | Decreasing Energy Consumption | Decreasing Business Waste | Decreasing Environmental Cost | Revenues | Cost-Oriented | Revenue-Oriented | Increase in Quality | Increasing Efficiency | Improving Green Manufacturing | Improving Green Packaging | Improving Green/Eco Design | Improving Green Logistics | Improving Reverse Logistics | Improving Green Purchasing | Improving Green Image | Incorporating Environmental Management | Green information systems | Increasing Customer Satisfaction | Improving Cooperation/Collaboration with Customers | Marketing Measures |
| ENVIRONMENTAL PERFORMANCE | Decreasing Emissions | 0.29 | 0.31 | 0.32 | 0.35 | 0.31 | 0.36 | 0.31 | 0.26 | 0.27 | 0.36 | 0.27 | 0.33 | 0.28 | 0.28 | 0.31 | 0.38 | 0.36 | 0.30 | 0.29 | 0.25 | 0.31 |
| | Decreasing Energy Consumption | 0.33 | 0.26 | 0.29 | 0.32 | 0.30 | 0.35 | 0.32 | 0.25 | 0.25 | 0.34 | 0.26 | 0.31 | 0.26 | 0.25 | 0.28 | 0.36 | 0.33 | 0.28 | 0.27 | 0.23 | 0.29 |
| | Decreasing Business Waste | 0.33 | 0.30 | 0.26 | 0.35 | 0.30 | 0.33 | 0.31 | 0.25 | 0.24 | 0.34 | 0.26 | 0.31 | 0.25 | 0.26 | 0.28 | 0.37 | 0.34 | 0.28 | 0.28 | 0.23 | 0.29 |
| | Decreasing Environmental Cost | 0.30 | 0.29 | 0.30 | 0.27 | 0.28 | 0.32 | 0.30 | 0.24 | 0.23 | 0.32 | 0.26 | 0.30 | 0.26 | 0.25 | 0.28 | 0.35 | 0.32 | 0.27 | 0.26 | 0.23 | 0.28 |
| | Revenues | 0.34 | 0.32 | 0.32 | 0.33 | 0.26 | 0.34 | 0.33 | 0.26 | 0.25 | 0.35 | 0.27 | 0.32 | 0.27 | 0.27 | 0.29 | 0.37 | 0.34 | 0.29 | 0.27 | 0.24 | 0.29 |
| ECONOMIC/FINANCIAL PERFORMANCE | Cost-Oriented | 0.31 | 0.32 | 0.30 | 0.33 | 0.29 | 0.30 | 0.32 | 0.26 | 0.27 | 0.33 | 0.28 | 0.32 | 0.28 | 0.28 | 0.30 | 0.36 | 0.33 | 0.29 | 0.30 | 0.26 | 0.32 |
| | Revenue-Oriented | 0.31 | 0.32 | 0.30 | 0.32 | 0.30 | 0.33 | 0.27 | 0.27 | 0.27 | 0.32 | 0.27 | 0.31 | 0.27 | 0.27 | 0.29 | 0.34 | 0.32 | 0.28 | 0.29 | 0.26 | 0.31 |
| OPERATIONAL PERFORMANCE | Increase in Quality | 0.26 | 0.26 | 0.25 | 0.27 | 0.23 | 0.30 | 0.27 | 0.18 | 0.21 | 0.27 | 0.22 | 0.26 | 0.22 | 0.21 | 0.23 | 0.29 | 0.26 | 0.23 | 0.27 | 0.23 | 0.28 |
| | Increasing Efficiency | 0.34 | 0.33 | 0.30 | 0.34 | 0.30 | 0.35 | 0.32 | 0.27 | 0.22 | 0.32 | 0.26 | 0.31 | 0.26 | 0.27 | 0.27 | 0.35 | 0.34 | 0.29 | 0.29 | 0.24 | 0.31 |
| | Improving Green Manufacturing | 0.38 | 0.36 | 0.35 | 0.37 | 0.35 | 0.38 | 0.34 | 0.28 | 0.28 | 0.34 | 0.31 | 0.36 | 0.30 | 0.30 | 0.31 | 0.43 | 0.38 | 0.33 | 0.32 | 0.27 | 0.34 |
| | Improving Green Packaging | 0.31 | 0.29 | 0.30 | 0.33 | 0.28 | 0.32 | 0.29 | 0.23 | 0.23 | 0.34 | 0.23 | 0.33 | 0.27 | 0.26 | 0.29 | 0.38 | 0.34 | 0.28 | 0.28 | 0.24 | 0.30 |
| | Improving Green/Eco Design | 0.37 | 0.34 | 0.34 | 0.37 | 0.33 | 0.37 | 0.34 | 0.27 | 0.27 | 0.38 | 0.31 | 0.31 | 0.30 | 0.29 | 0.33 | 0.41 | 0.38 | 0.32 | 0.31 | 0.26 | 0.33 |
| LOGISTICS PERFORMANCE | Improving Green Logistics | 0.33 | 0.32 | 0.29 | 0.34 | 0.28 | 0.34 | 0.30 | 0.24 | 0.24 | 0.35 | 0.26 | 0.31 | 0.24 | 0.27 | 0.30 | 0.37 | 0.35 | 0.30 | 0.29 | 0.24 | 0.30 |
| | Improving Reverse Logistics | 0.30 | 0.30 | 0.29 | 0.31 | 0.28 | 0.31 | 0.28 | 0.23 | 0.23 | 0.33 | 0.24 | 0.29 | 0.27 | 0.22 | 0.28 | 0.35 | 0.32 | 0.26 | 0.26 | 0.22 | 0.27 |
| | Improving Green Purchasing | 0.37 | 0.33 | 0.33 | 0.36 | 0.32 | 0.36 | 0.32 | 0.27 | 0.27 | 0.37 | 0.30 | 0.34 | 0.31 | 0.29 | 0.27 | 0.40 | 0.36 | 0.31 | 0.30 | 0.24 | 0.31 |
| ORGANIZATIONAL PERFORMANCE | Improving Green Image | 0.30 | 0.27 | 0.29 | 0.30 | 0.28 | 0.30 | 0.28 | 0.23 | 0.22 | 0.32 | 0.26 | 0.29 | 0.25 | 0.25 | 0.28 | 0.29 | 0.33 | 0.27 | 0.26 | 0.22 | 0.28 |
| | Incorporating environmental management | 0.35 | 0.33 | 0.34 | 0.36 | 0.32 | 0.35 | 0.32 | 0.26 | 0.26 | 0.38 | 0.30 | 0.35 | 0.30 | 0.29 | 0.32 | 0.40 | 0.32 | 0.32 | 0.30 | 0.26 | 0.31 |
| | Green information systems | 0.31 | 0.29 | 0.30 | 0.32 | 0.29 | 0.31 | 0.29 | 0.24 | 0.23 | 0.34 | 0.27 | 0.32 | 0.27 | 0.26 | 0.29 | 0.36 | 0.33 | 0.24 | 0.26 | 0.23 | 0.27 |
| MARKETING PERFORMANCE | Increasing Customer Satisfaction | 0.21 | 0.20 | 0.20 | 0.22 | 0.19 | 0.24 | 0.24 | 0.19 | 0.17 | 0.23 | 0.19 | 0.22 | 0.20 | 0.18 | 0.20 | 0.24 | 0.22 | 0.19 | 0.17 | 0.19 | 0.23 |
| | Improving Cooperation/Collaboration with Customers | 0.26 | 0.26 | 0.26 | 0.29 | 0.25 | 0.29 | 0.29 | 0.24 | 0.23 | 0.30 | 0.24 | 0.28 | 0.24 | 0.23 | 0.25 | 0.31 | 0.28 | 0.26 | 0.29 | 0.19 | 0.30 |
| | Marketing Measures | 0.25 | 0.24 | 0.24 | 0.26 | 0.23 | 0.27 | 0.26 | 0.21 | 0.21 | 0.27 | 0.23 | 0.26 | 0.22 | 0.21 | 0.22 | 0.28 | 0.25 | 0.23 | 0.25 | 0.22 | 0.21 |