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*Review Article*

# Evaluating Agile Practices in Green Supply Chain Management Using a Fuzzy Multicriteria Approach

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Ensuring the successful implementation of sustainable development goals in each country today depends heavily on the preservation and optimal use of its limited irreplaceable resources; therefore, a wide range of measures have been thus far taken by governments to deal with this issue. The study's main aim is to evaluate agile practices in green supply chain management utilizing a fuzzy multicriteria approach. To meet that aim, a quantitative research design was carried out by collecting data from fieldwork in the form of completing a questionnaire. Based on the results, the global spread of environmental standards along with the growing consumer demand for integrating green product supply into supply chain management (SCM), encompassing all practices associated with the flow of goods from the extraction and use of raw materials to delivery to end consumers as well as the flow of information throughout this chain, has accordingly given rise to the novel concept of green supply chain management (GSCM). Finally, GSCM criteria were identified and then prioritized, exploiting a fuzzy multicriteria approach in the present study.

## 1. Introduction

Green supply chain management (GSCM) emerged from the conventional supply chain management (SCM), wherein environmental compliance has been of utmost importance, aimed at reducing environmental pollution from different stages, namely, upstream to downstream, within the supply chain [1]. GSCM practices have thus developed into emerging activity-based management that can help improve competitiveness in the bioindustrial sector and even reflect on environmental actions and economic performance. Many studies have so far reported how GSCM practices can lead to a decline in the environmental burden of production operations and residues as well as an increase in the competitiveness of the industry [2]. GSCM also seeks to remove or lessen negative environmental impacts (namely, air, water, and soil pollution) and waste resources (namely, energy, materials, and products) from the extraction or exploitation of raw materials to the final consumption of products [3]. Thus, GSCM practices are assumed as key concepts, incorporating environmental thinking into product design, production process, raw material selection and sourcing, final product delivery, and life cycle SCM [4]. In this sense, Cao and Chen [5]reported that environmental issues such as greenhouse gas emissions, resource extraction and production, and reusing and recycling, arising from all product life cycle stages, can be implemented during specific activities at different levels, whose acceptance could lead to limited resources and reduce the environmental burden. Thus, GSCM practices are thought of as one of the major approaches to profitability, which help maximize market share and diminish destructive environmental risks and impacts [6]. The presence of several decision-making criteria affecting GSCM in numerous organizations along with the occurrence of multiple goals in the nature of this type of management has consequently made it a significantly challenging issue in decision theory, which should be considered in the literature of industrial engineering and operations management. In general, creating GSCM and paying much more attention to environmental issues can relegate costs, improve environmental performance, and strengthen the reputation of companies and organizations [3, 7].

Nevertheless, managers usually regard environmental management, sometimes even energy management, as a decelerating and costly factor, with no economic justification in this sense. Among the main principles from Chapter 8 of the Rio Declaration of 1992 is the effective use of economic instruments and market mechanisms as well as other incentives to realize sustainable development. Article 14 of Johannesburg Summit 2002—the World Summit on Sustainable Development—also emphasizes sustainable production and consumption policies in companies and organizations to attain this goal [8]. Considering environmental concerns, induced to new heights over the past decades, environmental pollution and SCM development must be addressed because such practices can play an important role in preventing the waste of financial, human, and time resources and even revolutionizing energy consumption structure in production/service industry. Operational solutions to this problem should be thus combined in the form of a comprehensive SCM approach [6].

Despite the increasing development and adoption of environmental management strategies in many mining companies worldwide, there are still some significant research topics on environmental issues, particularly GSCM practices. SCM has also turned into a common practice at the industry level and numerous articles on its theories and practices have been so far published, although the evaluation of supply chain performance has received little attention [7–12]. Overall, minimal effort has been made to systematically identify the evaluation criteria for supply chain performance. In addition, no consensus exists among researchers on the most appropriate method to prioritize such criteria [13–15].

The contributions of this study through the investigation of green supply chain management can be defined as follows:

(i) GSCM may help prevent the use of toxic and hazardous chemicals

(ii) The nature and advantages of GSCM can be applied to all parts of an organization

(iii) Supply chain greening can benefit companies and organizations at both individual and national levels

(iv) GSCM programs can provide particular competitive benefits, including lower costs, and greener products

## 2. Literature Review

*2.1. SCM Theoretical Foundations.* The term "supply chain" was first invented by Banbury in the mid-1970s and then applied to pass on electricity to the ultimate consumer. In the 1960–1970s, companies and organizations also sought to improve their competitiveness by standardizing and boosting their internal processes to produce better-quality and lower-cost products. The prevailing view at the time was that strong engineering and design, as well as coherent production operations, could be a prerequisite to meeting market demands and thus gaining more market share. For this reason, companies and organizations focused on augmenting efficiency. In the 1980s, with the wide variety of customer behavior patterns, companies and organizations became increasingly interested in expanding product line flexibility and developing new products to serve consumer needs. The 1990s was accordingly the period of improvement in the production processes and the exploitation of reengineering patterns. In order to keep their presence and multiply their market share, the leaders of many industries and factories also realized that developing internal processes and flexibility in the production process and increasing the quality and reducing the costs of raw materials were among the critical factors in achieving the above-mentioned goals. Over the last years of the second millennium and the start of the 21st century, successful companies and organizations correspondingly found that a new approach to SCM based on information technology (IT) was needed given the rapid development of IT in recent years and its widespread use around the world, so electronic commerce (e-commerce) could be the factor of their superiority in competitive markets [3, 10, 16, 17].

*2.2. GSCM.* In 1976, two American scholars asserted that some synthetic chemicals would damage the ozone layer. Scientific research also substantiated this theory and found evidence that ozone depletion was much faster than that proposed in some estimates and models. Considering the need to take measures to solve this problem and upon the call by the United Nations in 1985, the representatives of 21 countries, and the member states of the European Economic Community (EEC) met in Vienna, to talk about the global policy to fight against the destruction of the ozone layer. In 1987, the report of the World Commission on Environment and Development, known as the Brundtland Report, was published entitled "Our Common Future" and more than 50 world leaders supported it in 1988 [6, 17–19]. GSCM was thus introduced by the Michigan State University Industrial Research Association in 1996, as a novel management model for environmental protection. Here, GSCM from the perspective of the product life cycle included all stages of raw materials, product design and manufacturing, product sales and transfer, as well as product reusing and recycling. Exploiting SCM along with green technologies, companies and organizations could accordingly reduce the negative environmental impacts and achieve the preservation and optimal use of energy resources [20–22].

*2.3. Green Approach to SCM.* Following the spread of natural pollutants, much attention has been thus far paid to the negative impacts of development measures, including those associated with industries, managers, and governments. The milestone of many efforts in this respect can be seen in the approval of the Johannesburg Summit 2002. Therefore, green management seeks to reduce the negative consequences in the field of water, soil, air, climate, energy, and natural resources by using legal and cultural levers. Table 1 provides the summary of some environmental laws [23–26].

Sustainable SCM accordingly involves economic dimensions as well as environmental and social sustainability. For that reason, the concept of sustainable SCM is much broader than GSCM, which is merely one part of sustainable SCM. In the past, the product life cycle also encompassed processes from design to consumption, while it includes the processes of raw material preparation, design, construction, use and recycling, reusing, and the formation of a closed-loop material flow in the approach for environmental management to diminish resource consumption and harmful environmental impacts. GSCM also aims to change the traditional linear chain model from suppliers to users and then integrate recycling economics into SCM. By doing so, a closed-loop cyclic chain develops. If companies and organizations exploit GSCM, they can achieve relative success in terms of competitive advantages and resolve environmental problems. Furthermore, implementing GSCM can help avoid green barriers to global trade. Therefore, there is a need to move quickly toward implementing GSCM to seize much more opportunities, deal with some related challenges, and succeed.

## 3. Methodology

The present study with a quantitative research design was conducted by collecting data from fieldwork in the form of completing a questionnaire. In this way, according to the research topic and the main questions addressed to identify the criteria for GSCM practices in the mining industry, the related literature was reviewed, and then the criteria concerned were divided and organized. Afterward, based on the desired criteria, some items were summarized in a questionnaire in the form of pairwise comparison matrices. Upon preparing the questionnaire, it was distributed among managers and experts working in the field of the mining industry. After completing and collecting the questionnaires, the data were extracted, classified, and analyzed.

In this study, the statistical population consisted of experts who were among the most experienced people in the field of industry to evaluate GSCM practices in the mining industry. During the initial studies of the effective criteria, 37 experts working in the field of GSCM were selected. The expertise conditions in this research were having sufficient knowledge and at least ten years of work experience in this field along with a managerial position or specialization in GSCM with bachelor or higher degrees.

The questionnaire items were thus in two parts:

(A) The first part was an attempt to collect general and demographic characteristics information together with the history of work experience using general items.

(B) The second part contained specialized items in the form of pairwise comparison matrices to rank the criteria. After examining the available resources related to the evaluation of GSCM practices in the mining industry, Table 1 was drawn. Then, utilizing the factors given in Table 1, a research questionnaire was designed to weigh the key criteria affecting the evaluation of GSCM practices in the mining industry.

In order to check the validity of the given questionnaire using content validation methods, the items addressed were first reviewed by the experts and then the necessary corrections were made. As the data collection methods in the fuzzy multicriteria approach were established and the framework in this technique was specified, only some changes were made in the way of getting the responses and then the structure of the questionnaire was modified.

## 4. Results

Of the 11 subcriteria extracted in the former step, a survey matrix was prepared, so that the row items and column choices of this matrix consisted of the same subcriteria. The initial matrix was then provided to the experts as illustrated in the questionnaire and they were asked to numerically import the effect size of the row factors ($A$) on the column ones ($B$) between zero and four in the relevant cells via pairwise comparisons, and these numbers included the following concepts:

Zero (0): factor ($A$) has no effect on factor ($B$).

One (1): factor ($A$) has little effect on factor ($B$).

Two (2): factor ($A$) affects factor ($B$).

Three (3): factor ($A$) has a relatively large effect on factor ($B$).

Four (4): factor ($A$) has a strong effect on factor ($B$).

As emphasized in the questionnaire, the respected experts considered the following key points in the pairwise comparisons: first, rating only the direct relationship for the effect of row factors ($A$) on column ones ($B$) and not making a mistake due to a large number of matrix cells, so the inverse relationship meant the effect of column factors ($B$) on row ones ($A$) had not been taken into account, second, avoiding the indirect effect that row factor ($A$) had on column one ($B$) due to other factors in the problem because indirect effects automatically appeared in the final structure of the problem.

The matrices obtained from the second step were accordingly collected and the existence or nonexistence of a relationship between two factors was decided based on experts' consensus. If more than half of the group of experts had determined the effect size of a row factor ($A$) on column one ($B$) to be zero (0), it would confirm the effectiveness of the row factor ($A$). The same number of votes for a score greater than zero in a matrix cell could further prove the direct effect of row factor ($A$) on column one ($B$).

The median scores given by the experts were also directly related to the effect of the row subcriterion ($A$) on the

Table 1: GSCM criteria.

| No. | Criteria | Subcriteria | References |
|---|---|---|---|
| 1 | Quality | Defect rate, commitment to quality management, warranty policies, abnormal quality achievement, the International Organization for Standardization (ISO) quality management system, quality assurance, corrective and preventive actions, process improvement | [5, 8–12] |
| 2 | Price | Suitability of material price to market price, shipping costs, product pricing, ordering costs | [5, 8–10, 12] |
| 3 | Technology | Technology readiness level, research and development (R&D) capability, current production facilities, supply chain technology development to meet current and future demands, technological compatibility, capacity, pollution prevention | [8–13] |
| 4 | Delivery | Order execution, warehouse management supplier, delivery reliability, appropriate delivery date, timeliness, product development skills, delay time, supplier flexibility | [5, 8–10, 13] |
| 5 | Environmental management | Environmental certification such as ISO 14000, ecoefficiency, the restriction of hazardous substances (RoHS) directive 2002/95/EC compliance, environmental protection program, environmental policy, continuous monitoring in compliance, green process planning system | [8, 11–15] |
| 6 | Pollution control | Air pollution, pollution control plan, water and wastewater, average volume of air pollutants, solid waste, release of harmful materials | [8, 9, 11, 15] |
| 7 | Green innovation | Green technologies, green process, production planning, renewable product design, product redesign, green design, product design, material recycling | [5, 8, 12, 13] |
| 8 | Hazardous material management | Hazardous material management, process audit, inventory of hazardous materials, prevention of material mix-up, ozone-depleting chemicals, harmful substance use | [5, 8, 11] |
| 9 | Green image | Ratio of green consumers to total consumers, materials used in components of supply to reduce impacts on natural resources, social responsibility, ability to change trends and products to reduce impacts on natural resources, stakeholder relations | [8–11, 13] |
| 10 | Green product | Recycling, disposal costs of components, green production, green packaging, green product certification, disposal, use of recycled and nontoxic materials | [8, 11] |
| 11 | Competencies | Distinctive competencies, decentralized decision-making, emphasis on core competence, trust-based relationships, team-oriented goals and criteria, incentive structures for innovation, vertical integration | [6, 16, 17] |

column subcriterion ($B$) for each of the relationships endorsed in the previous step.

According to the third and fourth steps, an $X$ matrix was formed. In this step, the corresponding diagram with the $X$ matrix could be drawn as the initial one, so that its vertices were the same as the components of the system and its arc was equal to the degrees of direct relationships between both criteria of the system and the effect size of each direct relationship on the corresponding arc. Obviously, the effect size of zero (0) indicated the lack of a direct relationship in pairwise comparisons, and thus no arc was drawn for it (Table 2).

*4.1. Matrix Formation.* Each input in the $X$ matrix was multiplied by the "inverse of the largest sum of the rows of that matrix ($\lambda$)" to obtain the $X$ matrix, which represented the relative effect size of the direct relationships in the system (Table 3).

$$(M = \lambda * X). \tag{1}$$

*4.2. S Matrix Formation.* An $S$ matrix was formed, which denoted the relative effect size of direct and indirect relationships (Table 4).

$$S = M(I - M)^{-1}. \tag{2}$$

## 5. Discussion

In the $S$ matrix, the row sum of the entries ($R$), the column sum of the entries ($J$), the sum ($R + J$), and the difference ($R - J$) were calculated. The value ($R$) for each factor denoted the degree of the effect of that factor on other system factors and the corresponding value ($J$) showed the effect of the given factor on other system factors. Therefore, ($R + J$) could determine the sum of the effect of the desired factor in the system; in other words, the factor that had the highest value could have the most frequent interactions with other factors in the system (Figures 1–4). The final value of the effect of each factor on the sum of other system factors was additionally obtained from the difference ($R - J$), so:

If $R > J \longrightarrow R - J > 0$, then the factor involved had a definite effect size.

If $R < J \longrightarrow R - J < 0$, then the factor desired had a definite effect size.

Upon performing the calculations by the software, the values of ($R$), ($J$), ($R + J$), and ($R - J$) were also obtained according to Tables 5 and 6.

Best nonfuzzy performance (BNP) was further applied for fuzzy decoupling control purposes, as shown below.

$$\text{BNP} = \frac{(u - l) + (m - l)}{3}. \tag{3}$$

By arranging the values of ($R$), ($J$), ($R + J$), and ($R - J$) in descending order, Tables 7 and 8 were obtained.

Table 2: The $X$ matrix of the effect size governing direct relationships in the system in a fuzzy form.

| | Quality C1 | Price C2 | Technology C3 | Delivery C4 | Environmental management C5 | Pollution control C6 | Green innovation C7 | Hazardous material management C8 | Green image C9 | Green product C10 | Competencies C11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | (0, 0, 0.25) | (0, 0.25, 0.25) | (0.25, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.5) | (0.75, 0.5, 0.75) | (0.5, 0.75, 1) | (0.75, 1, 0.25) | (1, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.5) |
| C2 | (0, 0.25, 0.5) | (0.25, 0.5, 0) | (0.5, 0, 0) | (0, 0, 0.25) | (0, 0.25, 0.25) | (0.25, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.5) | (0.75, 0.5, 0.75) | (0.5, 0.75, 1) | (0.75, 1, 0.25) |
| C3 | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0) | (0.75, 0, 0) | (0, 0, 0.25) | (0, 0.25, 0.25) | (0.25, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) |
| C4 | (0.5, 0.75, 1) | (0.75, 1, 0.25) | (1, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0) | (0.75, 0, 0) | (0, 0, 0.25) | (0, 0.25, 0.25) |
| C5 | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.5) | (0.75, 0.5, 0.75) | (0.5, 0.75, 1) | (0.75, 1, 0.25) | (1, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0) |
| C6 | (0, 0.25, 0.5) | (0.25, 0.5, 0) | (0.5, 0, 0.25) | (0, 0.25, 0.5) | (0.25, 0.5, 0.25) | (0.5, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) |
| C7 | (0, 0.25, 0.5) | (0.25, 0.5, 0.25) | (0.5, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.5) | (0.75, 0.5, 0.75) | (0.5, 0.75, 1) | (0.75, 1, 0.25) |
| C8 | (0, 0.25, 0.5) | (0.25, 0.5, 0.25) | (0.5, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) |
| C9 | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.5) | (0.75, 0.5, 0.75) | (0.5, 0.75, 1) | (0.75, 1, 0.25) | (1, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) |
| C10 | (0, 0.25, 0.5) | (0.25, 0.5, 0.25) | (0.5, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.5) | (0.75, 0.5, 0.75) | (0.5, 0.75, 1) | (0.75, 1, 0.5) |
| C11 | (0, 0, 0.25) | (0, 0.25, 0) | (0.25, 0, 0.25) | (0, 0.25, 0.5) | (0.25, 0.5, 0.25) | (0.5, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) | (0.75, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 0.25) |

Table 3: The $M$ matrix of the effect size governing direct relationships in the system in a normalized fuzzy form.

| | $C1$ | $C2$ | $C3$ | $C4$ | $C5$ | $C6$ | $C7$ | $C8$ | $C9$ | $C10$ | $C11$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $C1$ | (0, 0, 0.03) | (0, 0.03, 0.03) | (0.03, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.06) | (0.08, 0.06, 0.08) | (0.06, 0.08, 0.11) | (0.08, 0.11, 0.03) | (0.11, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.06) |
| $C2$ | (0, 0.03, 0.06) | (0.03, 0.06, 0) | (0.06, 0, 0) | (0, 0, 0.03) | (0, 0.03, 0.03) | (0.03, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.06) | (0.08, 0.06, 0.08) | (0.06, 0.08, 0.11) | (0.08, 0.11, 0.03) |
| $C3$ | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0) | (0.08, 0, 0) | (0, 0, 0.03) | (0, 0.03, 0.03) | (0.03, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) |
| $C4$ | (0.06, 0.08, 0.11) | (0.08, 0.11, 0.03) | (0.11, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0) | (0.08, 0, 0) | (0, 0, 0.03) | (0, 0.03, 0.03) |
| $C5$ | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.06) | (0.08, 0.06, 0.08) | (0.06, 0.08, 0.11) | (0.08, 0.11, 0.03) | (0.11, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0) |
| $C6$ | (0, 0.03, 0.06) | (0.03, 0.06, 0) | (0.06, 0, 0.03) | (0, 0.03, 0.06) | (0.03, 0.06, 0.03) | (0.06, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) |
| $C7$ | (0, 0.03, 0.06) | (0.03, 0.06, 0.03) | (0.06, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.06) | (0.08, 0.06, 0.08) | (0.06, 0.08, 0.11) | (0.08, 0.11, 0.03) |
| $C8$ | (0, 0.03, 0.06) | (0.03, 0.06, 0.03) | (0.06, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) |
| $C9$ | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.06) | (0.08, 0.06, 0.08) | (0.06, 0.08, 0.11) | (0.08, 0.11, 0.03) | (0.11, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) |
| $C10$ | (0, 0.03, 0.06) | (0.03, 0.06, 0.03) | (0.06, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.06) | (0.08, 0.06, 0.08) | (0.06, 0.08, 0.11) | (0.08, 0.11, 0.06) |
| $C11$ | (0, 0, 0.03) | (0, 0.03, 0) | (0.03, 0, 0.03) | (0, 0.03, 0.06) | (0.03, 0.06, 0.03) | (0.06, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) | (0.08, 0.03, 0.06) | (0.03, 0.06, 0.08) | (0.06, 0.08, 0.03) |

TABLE 4: The $S$ matrix indicating the relative effect size of direct and indirect relationships in a fuzzy form.

| | $C1$ | $C2$ | $C3$ | $C4$ | $C5$ | $C6$ | $C7$ | $C8$ | $C9$ | $C10$ | $C11$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $C1$ | (0.01, 0.05, 0.31) | (0.04, 0.12, 0.39) | (0.07, 0.16, 0.46) | (0.04, 0.14, 0.43) | (0.07, 0.15, 0.45) | (0.04, 0.13, 0.4) | (0.02, 0.11, 0.41) | (0.01, 0.09, 0.35) | (0.04, 0.13, 0.4) | (0.04, 0.13, 0.29) | (0.04, 0.11, 0.36) |
| $C2$ | (0.01, 0.08, 0.33) | (0.01, 0.07, 0.33) | (0.04, 0.14, 0.42) | (0.07, 0.15, 0.45) | (0.04, 0.13, 0.41) | (0.04, 0.12, 0.39) | (0.04, 0.14, 0.42) | (0.04, 0.12, 0.36) | (0.04, 0.12, 0.39) | (0.04, 0.13, 0.28) | (0.01, 0.08, 0.34) |
| $C3$ | (0.04, 0.11, 0.35) | (0.04, 0.13, 0.38) | (0.02, 0.08, 0.38) | (0.05, 0.14, 0.42) | (0.04, 0.14, 0.41) | (0.04, 0.13, 0.39) | (0.04, 0.14, 0.42) | (0.04, 0.12, 0.37) | (0.04, 0.13, 0.39) | (0.07, 0.15, 0.3) | (0.01, 0.09, 0.34) |
| $C4$ | (0.07, 0.13, 0.39) | (0.04, 0.13, 0.39) | (0.05, 0.14, 0.44) | (0.02, 0.09, 0.39) | (0.05, 0.14, 0.43) | (0.04, 0.13, 0.41) | (0.07, 0.16, 0.46) | (0.04, 0.12, 0.38) | (0.04, 0.13, 0.41) | (0.04, 0.13, 0.3) | (0.01, 0.09, 0.35) |
| $C5$ | (0.04, 0.11, 0.37) | (0.04, 0.13, 0.4) | (0.08, 0.16, 0.48) | (0.05, 0.15, 0.45) | (0.02, 0.09, 0.39) | (0.07, 0.15, 0.44) | (0.07, 0.16, 0.47) | (0.04, 0.12, 0.39) | (0.04, 0.13, 0.41) | (0.02, 0.11, 0.28) | (0.04, 0.12, 0.38) |
| $C6$ | (0, 0.07, 0.31) | (0.01, 0.09, 0.33) | (0.04, 0.12, 0.39) | (0.04, 0.13, 0.39) | (0.04, 0.12, 0.38) | (0.01, 0.06, 0.31) | (0.04, 0.12, 0.39) | (0, 0.08, 0.32) | (0.01, 0.09, 0.34) | (0.04, 0.12, 0.26) | (0.03, 0.1, 0.33) |
| $C7$ | (0.01, 0.09, 0.34) | (0.04, 0.13, 0.39) | (0.05, 0.14, 0.44) | (0.08, 0.16, 0.46) | (0.04, 0.14, 0.42) | (0.04, 0.13, 0.4) | (0.02, 0.08, 0.38) | (0.04, 0.12, 0.38) | (0.04, 0.13, 0.4) | (0.07, 0.15, 0.31) | (0.03, 0.12, 0.37) |
| $C8$ | (0.01, 0.08, 0.33) | (0.04, 0.12, 0.38) | (0.04, 0.14, 0.42) | (0.04, 0.14, 0.42) | (0.04, 0.13, 0.41) | (0.04, 0.12, 0.39) | (0.04, 0.13, 0.41) | (0.01, 0.06, 0.32) | (0.07, 0.14, 0.41) | (0.04, 0.13, 0.28) | (0.01, 0.08, 0.34) |
| $C9$ | (0.04, 0.11, 0.36) | (0.04, 0.13, 0.38) | (0.07, 0.16, 0.46) | (0.05, 0.14, 0.43) | (0.04, 0.14, 0.41) | (0.01, 0.1, 0.38) | (0.04, 0.14, 0.42) | (0.04, 0.12, 0.37) | (0.01, 0.07, 0.35) | (0.04, 0.13, 0.29) | (0.03, 0.11, 0.36) |
| $C10$ | (0.01, 0.08, 0.33) | (0.04, 0.12, 0.37) | (0.04, 0.13, 0.42) | (0.07, 0.15, 0.45) | (0.07, 0.15, 0.43) | (0.01, 0.09, 0.37) | (0.07, 0.15, 0.44) | (0.01, 0.09, 0.34) | (0.01, 0.09, 0.37) | (0.01, 0.07, 0.23) | (0.01, 0.08, 0.33) |
| $C11$ | (0.01, 0.05, 0.27) | (0.01,0.08, 0.32) | (0.04, 0.12, 0.37) | (0.04, 0.12, 0.37) | (0.04, 0.12, 0.36) | (0.04, 0.11, 0.35) | (0.04, 0.12, 0.37) | (0.01, 0.08, 0.31) | (0.04, 0.11, 0.35) | (0.01, 0.09, 0.23) | (0, 0.05, 0.27) |

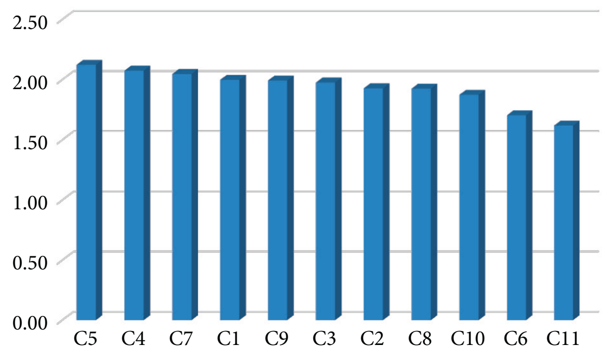


FIGURE 1: The impact of criteria.

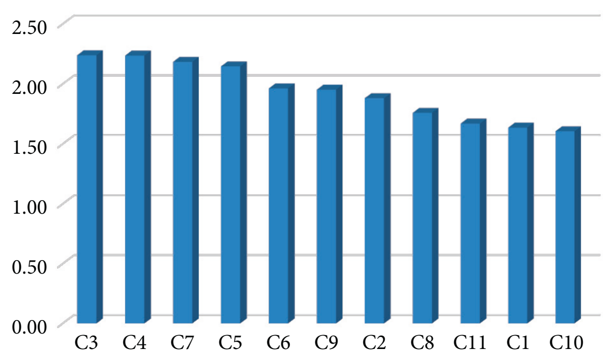


FIGURE 2: The effectiveness of criteria.

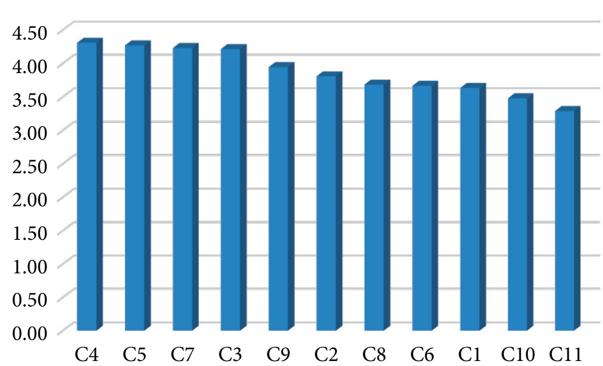


FIGURE 3: The sum of impact and effectiveness of criteria.

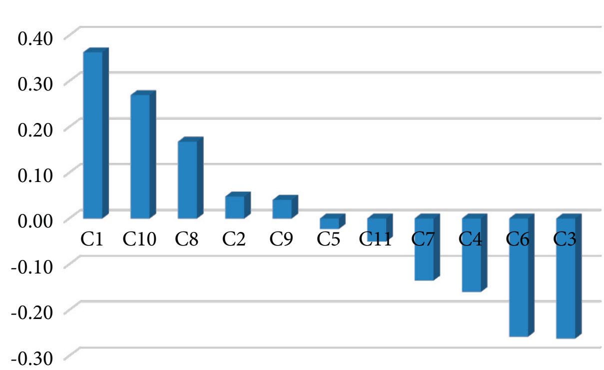


FIGURE 4: Difference between impact and effectiveness of criteria.

*5.1. Final Classified Diagram Formation.* A Cartesian coordinate system was initially established so that its longitudinal axis was calibrated in terms of values $(R+J)$ and its transverse axis was scaled with regard to $(R-J)$, and then the position of each of the existing criteria with a point in the coordinates "A: $(R+J,\ R-J)$" was specified on this system. The following diagram represents a simple view of the final structure of the system (Figure 5).

*5.2. Final Ranking of Subcriteria with respect to $(R+J)$ and $(R-J)$.* Although experts' judgments during pairwise comparisons are assumed simple and demand no knowledge of how the decision-making trial and evaluation laboratory (DEMATEL) works, the quality of their views on various aspects of an issue is very influential and thus provides sufficient information on it. For one problem, the DEMATEL method can be accordingly replicated several times and a proper structure can be completed by reviewing and revising the criteria of a system and their effect size. Other than the dependencies of the resulting weights (for the subcriteria) in expert opinions, such dependencies can be relative and obtained only with respect to the assumed criteria within the model but the effectiveness of each criterion of other factors outside the system is not taken into consideration. According to the information retrieved from the implementation of the preceding steps, the subcriteria in this study were ranked in terms of $(R+J)$ and $(R-J)$ in this section.

Green attitudes in companies and organizations along with the development of organizational structures called "green assurance" have thus far replaced organizational units including quality assurance. Supply chain greening accordingly refers to the process of reflecting on environmental criteria or considerations throughout SCM. GSCM can thus integrate SCM with environmental requirements into all stages of product design, raw material selection and supply, production and manufacturing, distribution and transfer processes, customer delivery, and finally, consumption services as well as recycling and reusing management to maximize the efficiency of energy resources and improve the performance of the entire supply chain. During the studies of the environmental impacts of SCM practices, the effects of products on the environment are often analyzed using a holistic approach (including the product life cycle from the onset to the end). Within this approach, all the ecological effects (namely, the examination of habits and lifestyles of creatures and their interactions with the environment) of each activity at different stages of the product life cycle, such as product concept, design, preparation of raw materials, production and manufacturing, assembly, storage, packaging, product transfer, and recycling and reusing are further measured and included in the product design.

GSCM has been accordingly recognized as one of the successful strategies to gain competitive advantages in manufacturing companies and organizations in recent years thanks to the benefits of cost reduction and innovation strategies in product manufacturing (namely, differentiation

Table 5: Values ($J$), ($R$), ($R+J$), and ($R-J$) in a fuzzy form.

| | $R$ | $J$ | $R+J$ | $R-J$ |
|---|---|---|---|---|
| $C1$ | (0.42, 1.33, 4.25) | (0.22, 0.98, 3.71) | (0.64, 2.3, 7.96) | (0.19, 0.35, 0.54) |
| $C2$ | (0.38, 1.29, 4.11) | (0.34, 1.25, 4.05) | (0.72, 2.54, 8.17) | (0.04, 0.04, 0.06) |
| $C3$ | (0.42, 1.35, 4.16) | (0.54, 1.5, 4.68) | (0.95, 2.85, 8.84) | (−0.12, −0.14, −0.53) |
| $C4$ | (0.46, 1.4, 4.36) | (0.54, 1.5, 4.66) | (1, 2.9, 9.02) | (−0.08, −0.1, −0.3) |
| $C5$ | (0.5, 1.44, 4.44) | (0.49, 1.45, 4.49) | (0.99, 2.89, 8.93) | (0, −0.01, −0.06) |
| $C6$ | (0.25, 1.11, 3.75) | (0.38, 1.28, 4.22) | (0.63, 2.39, 7.98) | (−0.13, −0.18, −0.47) |
| $C7$ | (0.46, 1.39, 4.3) | (0.51, 1.45, 4.59) | (0.97, 2.84, 8.88) | (−0.05, −0.06, −0.29) |
| $C8$ | (0.38, 1.29, 4.11) | (0.26, 1.12, 3.89) | (0.64, 2.41, 7.99) | (0.12, 0.17, 0.22) |
| $C9$ | (0.42, 1.35, 4.2) | (0.37, 1.28, 4.21) | (0.79, 2.63, 8.41) | (0.05, 0.08, 0) |
| $C10$ | (0.35, 1.19, 4.08) | (0.43, 1.33, 3.05) | (0.78, 2.52, 7.14) | (−0.08, −0.14, 1.03) |
| $C11$ | (0.26, 1.05, 3.56) | (0.21, 1.04, 3.76) | (0.46, 2.08, 7.32) | (0.05, 0.01, −0.2) |

Table 6: Values ($J$), ($R$), ($R+J$), and ($R-J$) in a nonfuzzy form (definite).

| | $R$ | $J$ | $R+J$ | $R-J$ |
|---|---|---|---|---|
| $C1$ | 2.00 | 1.64 | 3.63 | 0.36 |
| $C2$ | 1.93 | 1.88 | 3.81 | 0.05 |
| $C3$ | 1.98 | 2.24 | 4.21 | −0.26 |
| $C4$ | 2.07 | 2.24 | 4.31 | −0.16 |
| $C5$ | 2.12 | 2.15 | 4.27 | −0.02 |
| $C6$ | 1.70 | 1.96 | 3.67 | −0.26 |
| $C7$ | 2.05 | 2.18 | 4.23 | −0.14 |
| $C8$ | 1.93 | 1.76 | 3.68 | 0.17 |
| $C9$ | 1.99 | 1.95 | 3.94 | 0.04 |
| $C10$ | 1.87 | 1.60 | 3.48 | 0.27 |
| $C11$ | 1.62 | 1.67 | 3.29 | −0.05 |

Table 7: The order of impact and effectiveness of subcriteria in relation to each other.

| Priority | Impact | $R$ | Priority | Effectiveness | $J$ |
|---|---|---|---|---|---|
| 1 | $C5$ | 2.12 | 1 | $C3$ | 2.24 |
| 2 | $C4$ | 2.07 | 2 | $C4$ | 2.24 |
| 3 | $C7$ | 2.05 | 3 | $C7$ | 2.18 |
| 4 | $C1$ | 2.00 | 4 | $C5$ | 2.15 |
| 5 | $C9$ | 1.99 | 5 | $C6$ | 1.96 |
| 6 | $C3$ | 1.98 | 6 | $C9$ | 1.95 |
| 7 | $C2$ | 1.93 | 7 | $C2$ | 1.88 |
| 8 | $C8$ | 1.93 | 8 | $C8$ | 1.76 |
| 9 | $C10$ | 1.87 | 9 | $C11$ | 1.67 |
| 10 | $C6$ | 1.70 | 10 | $C1$ | 1.64 |
| 11 | $C11$ | 1.62 | 11 | $C10$ | 1.60 |

Table 8: The order of the final impact of subcriteria on other subcriteria and their final importance in the system.

| No. | Weight priority based on interaction | $R+J$ | No. | Priority based on net impact/effectiveness intensity | $R-J$ | |
|---|---|---|---|---|---|---|
| 1 | $C4$ | 4.31 | 1 | $C1$ | 0.36 | |
| 2 | $C5$ | 4.27 | 2 | $C10$ | 0.27 | |
| 3 | $C7$ | 4.23 | 3 | $C8$ | 0.17 | Impact criteria ($R-J>0$) |
| 4 | $C3$ | 4.21 | 4 | $C2$ | 0.05 | |
| 5 | $C9$ | 3.94 | 5 | $C9$ | 0.04 | |
| 6 | $C2$ | 3.81 | 6 | $C5$ | −0.02 | |
| 7 | $C8$ | 3.68 | 7 | $C11$ | −0.05 | |
| 8 | $C6$ | 3.67 | 8 | $C7$ | −0.14 | Effective criteria ($R-J<0$) |
| 9 | $C1$ | 3.63 | 9 | $C4$ | −0.16 | |
| 10 | $C10$ | 3.48 | 10 | $C6$ | −0.26 | |
| 11 | $C11$ | 3.29 | 11 | $C3$ | −0.26 | |

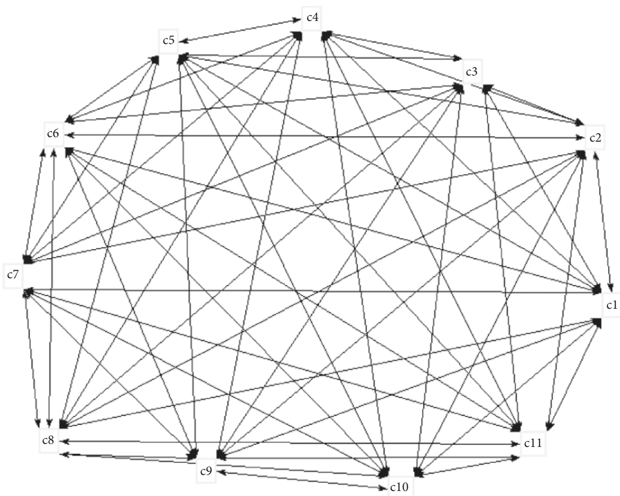


Figure 5: Final classified diagram.

strategy). GSCM can also lead to the faster delivery of goods and services, reduce inactivity, lower costs, increase quality, and even give rise to competitive advantages by creating more value-added for consumers following the supply of green products. Moreover, GSCM seeks to change the traditional linear chain model from suppliers to users and then integrate recycling economics into SCM. By doing so, a closed-loop cyclic chain develops. If companies and organizations exploit GSCM, they can achieve relative success in terms of competitive advantages and deal with environmental problems. Furthermore, implementing GSCM can help avoid green barriers to global trade. Therefore, there is a dire need to move quickly toward implementing GSCM to seize much more opportunities, tackle some related challenges, and succeed. Various large companies, such as General Motors Co., Hewlett-Packard, Procter and Gamble Co., Nike Inc., and many others, have thus developed a good reputation and brand image for green products through GSCM research and implementation. In recent centuries, the need to evaluate and select technologies to minimize the destructive effects of manufacturing activities in various industries on the environment is also rising in such a way that industrial development has given way to sustainable development.

Optimizing production devices and hardware in order to boost efficiency and moderate environmental pollution should be thus considered. The utilization of new technologies and more scientific production line design can also diminish production waste as well as defective products. The use of advanced and high-tech devices can even lead to less depreciation.

Here, reverse logistics includes the process of returning goods and dealing appropriately with such items to increase the efficiency and profitability of logistics organizations. On the other hand, the impact and effectiveness of manufacturers, suppliers, and customers thanks to these interactions, which are ultimately determined by quality, production time, product delivery time, customer satisfaction, and cost reduction, have made reverse logistics a big goal for all existing companies and organizations working with SCM. In general and traditionally, producers do not assume any responsibilities for their goods, after distribution and consumption by consumers, and do not even give a positive response to any obligations for their distributed and consumed products. However, today, the volume of products manufactured and consumed has caused considerable damage to the environment and everyone, including consumers and officials, is concerned about their environment, as highlighted in many studies [17].

Waste management and the preparation and enactment of laws on waste products have further led commodity producers to improve the production process. As disposing of waste and cleaning the environment cost a fortune, this strategy can be thus an optimal way to develop GSCM, as mentioned in Lin [18].

Besides, innovation strategy can be very effective in gaining a competitive advantage as it has been used by manufacturing companies and organizations in recent years. Companies and organizations adopting these strategies for GSCM can also try to exploit differentiation strategies and reduce the costs of environmental degradation by innovating in the design and production of green and recyclable products. The simultaneous combination of both strategies can accordingly bring a competitive advantage to most companies and organizations, as confirmed in Mageto [17].

Factories also manufacture their products with an environmental approach using an efficiency-based strategy and can consequently achieve greater operating profit. This requires better partnership and commitment between consumers and suppliers. The environmental benefit of this strategy is that it diminishes waste and thus resource use. This strategy also demands a more comprehensive specialized environment compared with that employed in a risk-based strategy, which was consistent with the results reported by Tseng and Chiu [19].

The finished product should be also in the direction of establishing GSCM. To fulfill this, manufactured products can be designed, produced, and presented in such a way that they consume less energy or at least make use of new and clean alternatives. The objective realization of this case can be thus observed in the production of fuel-efficient cars from Japan and the high popularity of this product among Americans, as mentioned in the study by Sarkis et al. [20].

Being green should be thus found in the whole SCM. Therefore, in each part, it must receive materials and components with the highest levels of environmental compatibility. Without this integration, GSCM establishment is practically impossible. In other words, better results can be merely achieved if greening is considered as supply chain integration. Otherwise, the output of one loop may become green for the next loops, for which this output is an input, but not green for the entire supply chain and fail to develop GSCM, in line with the results reported by Zhu et al. [12].

In terms of providing services and products, there is a need to have the production cycle with the highest percentage of output accuracy and health. Here, a percentage means that better basic facilities have been employed, which was in agreement with the establishment of GSCM because more errors in output products could mean the waste of basic facilities, wherein raw materials in many cases were normal and their waste is contrary to GSCM principles. Defects and breakdowns in the output product, in addition to the waste of raw materials, can also lead to the loss of various driving forces, using many natural materials for their production, which was consistent with the findings by Zhu et al. [12].

All products must be additionally returnable to the production line and even recyclable. If the output product is not reversible and repairable in case of failures in practice, its components and healthy parts may be wasted and eventually cause the waste of raw materials and manufacturing energies, as supported in the results of the research by Tseng et al. [21]. This recovery system should be accordingly designed so that the products are recycled after depreciation and inefficiency with a high percentage and some parts become the materials used in the industry, as confirmed in Zhu et al. [12].

All the items mentioned in this section can be fulfilled if training is fulfilled, especially in the human resources, having a big share in compliance with GSCM. Besides, R&D is of utmost importance because production and technology used to establish GSCM would not be accomplished without them, which was in line with the findings by Sarkis et al. [20].

## 6. Conclusion

In short, GSCM may associate the prevention of the use of toxic and hazardous chemicals or the reduction of pollutants or waste release into the environment. Although these are essential, the nature and benefits of GSCM can be applied to all parts of an organization, and its effects can extend to all tangible and intangible areas. Supply chain greening can also bring benefits to companies and organizations at both individual and national levels. At the individual level, GSCM programs can provide certain competitive advantages, such as lower costs, greener products, and better integration with suppliers, create markets for products, and help suppliers adapt better to environmental issues at the national level. Greening SCM can thus improve the competitive position of companies and organizations by reducing costs.

## Data Availability

The data used to support this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare there are no conflicts of interest.

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