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The green supplier selection as a key element in a supply chain: A review of cases studies

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Abstract
The current pressure of global competition is demanding faster, reliable, flexible, and cheaper products. Thus, in order to keep up with customer demands, companies need to continuously improve their manufacturing systems and develop new strategies. Supply chain management (SCM) is currently the most important tactic for modern companies to maintain their competitiveness. Supplier selection process (SSP) plays an important role in SCM and has been studied extensively in the past years as a tool to provide guidance and help to researchers and decision makers. Green supply chain management (GSCM) arose due to the recent increase in environmental protection. Consequently, the correspondent green supplier selection process (GSSP) has become more and more critical in GSCM. This paper presents a review of studies published in scientific journals during the last five years about green criteria utilized in multi-criterion decision making (MCDM) techniques for GSSP. Furthermore, it identifies the most commonly used MCDM techniques, in journals, universities, and academic departments where this type of research is being developed.

Keywords: Supply Chain Management (SCM); Green Supply Chain Management (GSCM); Supplier Selection Process (SSP); Green Supplier Selection Process (GSSP); Multi-criteria Decision Making (MCDM); Case Studies.

Selección de proveedores verde como un elemento clave en la cadena de suministro: Una revisión de casos de estudio

Resumen
La presión actual de la competencia global está demandando productos más rápidos, confiables, flexibles y más baratos; por lo tanto, con el fin de mantenerse al día con las demandas de los clientes, las empresas necesitan mejorar continuamente sus sistemas de fabricación y desarrollar nuevas estrategias. La gestión de la cadena de suministro (GCS) es actualmente la táctica más importante que utilizan las empresas modernas para mantener su competitividad. El proceso de selección de proveedores (PSP) desempeña un papel importante en la GCS y ha sido ampliamente estudiado en los últimos años como una herramienta para orientar y ayudar a los investigadores y tomadores de decisiones. La gestión de la cadena de suministro verde (GCSV) surge debido al reciente incremento en la protección del medio ambiente. Entonces, el proceso de selección de proveedores verde (PSPV) se ha convertido en un elemento crítico en la GCSV. El presente manuscrito muestra una revisión de los trabajos publicados en revistas científicas en los últimos 5 años sobre los criterios verdes utilizados en la decisión multicriterio. Además, identifica las técnicas de selección multicriterio (TSM) más utilizadas, revistas, universidades y departamentos académicos, donde este tipo de investigación se está desarrollando.

Palabras Clave: Gestión de la Cadena de Suministro (GCS); Gestión de la Cadena de Suministro Verde (GCSV); Proceso de Selección de Proveedores (PSP); Proceso de Selección de Proveedores Verde (PSPV); Técnicas de Selección Multicriterio (TSM); Casos de estudio.

1. Introduction

Supply chain management (SCM) is an important strategy used by contemporary companies. The members of the supply chain (SC) need to be able to solve the most critical processes concerning the correct supplier selection. Making the appropriate decision helps to reduce costs, improves quality, and promotes long-term relationships

between companies and suppliers, increasing company competitiveness. Therefore, the objective of supplier selection process (SSP) is to identify suppliers with the highest potential to fulfill the company's necessities.

Selecting a supplier is an extremely important step in the SC. The supplier will provide an organization with the adequate raw material or products at a competitive price. A supplier will also help improve environmental performance while avoiding hazardous substances and considering green design. With increasing government regulations and stronger public awareness in environmental protection, firms today cannot ignore environmental issues when selecting a supplier if they want to survive in the global market [1]. In order to respond to increasing environmental regulations, new terms have been created: green supply chain (GSC) and green supplier selection (GSS).

This paper presents a careful review of studies about the GSS process, highlighting the methods utilized to select a supplier. The studies reviewed were published in international journals from 2007 to 2013 that present a case of study related to GSS and emphasize the main green criteria and multi-criteria decision making (MCDM) techniques utilized in green supply chain management (GSCM).

The rest of this paper is organized as follows: In Section 2, a series of useful definitions related to SCM, GSCM, SSP, and GSS is provided. Section 3 presents the details of the methodology used for the literature review. Section 4 presents the information obtained in Section 3 and is organized by the following subsections: Distribution of papers published, green criteria utilized, MCDM techniques applied, journals publishing papers about GSS, countries, universities, and academic departments developing this type of research. The analysis of the results are shown in Section 5. Finally, in Section 6 the conclusions are shown.

2. The supplier selection process (SSP)

The evolution of supply relationships is underlined by the fact that suppliers are required to have an adequate set of competencies to be part of a supply system capable of facing market competition. Therefore, this section will describe the main concepts involved in the SSP within a SC.

2.1. Supply chain (SC)

Blanchard [2] defines the SC as the sequence of events that covers the entire lifecycle of a product or service from the beginning to the end, as can be seen in Fig. 1. It requires companies to be attentive throughout the whole manufacturing process, considering material delivery, material costs, manufacturing processes, distribution packaging, methods, and costs.

The SC can be extremely complex, since it integrates independent organizations that interact together to control and manage a product that will be used by an end customer [3]. If a member of the SC fails to deliver a component on time, there will be an impact in all of the other members of the SC. Therefore, the good integration of these independent companies will lead to a successful SC.

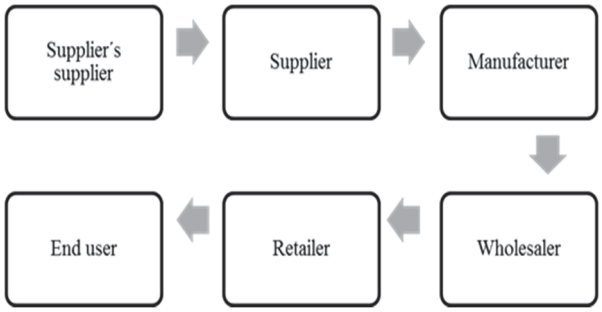

Figure 1. Supply chain's scope in a global company. Source: [2]

2.2. Supply chain management (SCM) and Green supply chain management (GSCM)

In the following subsections, we explain the SCM and GSCM systems.

2.2.1. Supply Chain Management (SCM)

According to Li and Wang [4], SCM integrates internal operational decisions and activities with external customer demands to be able to enhance competitiveness and profit (after production process). Su et al. [5] state that SCM reveals the advantages of coordination with suppliers (before production process). Thus, SCM has become a critical strategy for organizations to create competitive advantages, transforming suppliers and customers into partners. One of the reasons why a supplier is so important is because the cost of raw materials frequently represents 70% of the final product's cost. Therefore, the purchasing department plays an important role in reducing this total figure [6,7].

2.2.2. Green Supply Chain Management (GSCM)

Lee et al. [8] note that with growing worldwide awareness of environmental protection, green production has become an important issue for almost every manufacturer and will determine the sustainability of a manufacturer in the long term. GSCM is generally involves suppliers based on their environmental performance and business is only done with those that meet certain environmental regulations or standards [9].

Due to some violations in regulations, certain countries have taken action. For example, in 2001 more than 1.3 million boxes of PlayStation 2 games consoles, produced by the Sony Corporation, were blocked by the Dutch government due to an excessive amount of the toxic element Cadmium found in the cables of the game controls. This led to losses exceeding $130 million, and indirectly led to the re-inspection of over 6,000 factories and the establishment of a new supplier management system [10].

The previous is an example of the focus given to environmental care around the world and the importance that this trend has among leading companies in all fields. The fact that firms assess their environmental impact, regardless of the driver, represents significant growth in environmental awareness.

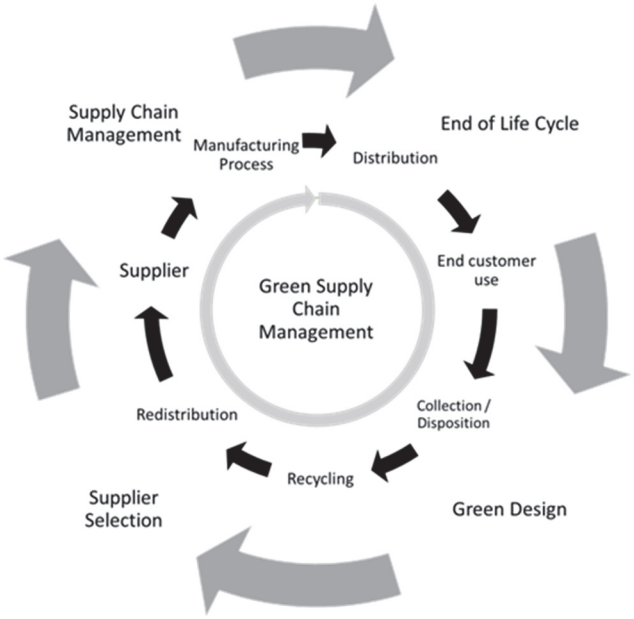

Figure 2. Work flow of a GSCM process.
Source: [11]

GSCM has been adopted as a strategy by leading industry companies to put pressure on their suppliers in order to achieve a certain level of environmental performance, stimulating operational cooperation of all SC members. The GSC approach seeks to reduce a product's ecological impact to a bare minimum. GSCM is, in essence, the same as a typical SCM. A typical example of how a GSCM works is shown in Fig. 2.

2.3. Supplier selection process (SSP)

As the first element in a SC, suppliers have a direct impact on the quality, cost, and delivery time of new products [12-14]. The supplier selection (SS) consists of measuring the performance of a group of suppliers to select the best option improving the effectiveness of the whole supply system.

SS is not an easy task, since various potential suppliers may have similar performance characteristics for different attributes. For many years, the traditional approach to SSP has mainly considered quality, cost, and lead time. However, currently, due to the environmental care issue, this is no longer enough, and companies have had to incorporate the environmental culture into the common SSP criteria.

A green supplier is expected, not only to achieve environmental compliance, but also to undertake efficient, green product design, and end-of-life cycle studies. Thus, in a GSC, companies need to have extensive SSP and performance evaluation processes [15]. A green supplier evaluation system is needed for a company to be able to meet the GSCM requirements and establish competitiveness. GSS is clearly a critical activity in purchasing, and buyers need to focus on the procurement of products and services from suppliers that can provide these with a low cost, good quality, short lead time, and environmental responsibility.

2.4. Evaluating attributes and Multi-criteria decision making (MCDM)

Decision making has always been a matter of concern for humankind. One of the most important tasks in decision making is to structure decision problems into a formal and manageable format [16]. Decision-making situations typically involve more than one attribute. MCDM has been created to help researchers and decision makers find the best solution to decision problems. There are several techniques, depending on the problem to be evaluated; however, all techniques follow the methodology suggested by De Boer et al. [17] for selecting a supplier:

- SSP definition
- Identification of criteria
- Supplier evaluation by chosen technique
- SS

In order to apply De Boer's methodology for SS, there has to be a way to determine and define the main attributes to be integrated into a technique for the SSP. The attributes used to evaluate a supplier fall into two classifications: quantitative and qualitative attributes.

2.4.1. Quantitative attributes

In simple terms, these attributes are composed of everything that can be measured and physically describe elements of a product, such as cost, speed, size, capacity, etc.

2.4.2. Qualitative attributes

These types of attributes are subjective; their application depends on the assigned weight, depending on the importance given to them by the organization. They describe products that need to be evaluated in a decision-making process to fulfill a requirement.

3. Material collection methodology

The literature review was undertaken in the 3 following steps: a) *Material collection*: The material to be collected is defined. b) *Review of articles*: The articles found were reviewed in order to obtain information to establish a categorization. c) *Information analysis*: For easy management of the article's information, classification software was used to generate tables and crosstabs showing data groups.

3.1. First step: Material collection

During this first step, a literature review was completed of English-language articles published in high-quality, peer-reviewed international journals between 2007 and 2013. The article search was performed in major databases such as: Science Direct, as a leading full-text scientific database that offers journal articles and book chapters; IEEE, which is considered the world's largest professional association for the advancement of technology; and ProQuest, which is a widely recognized dissertation database.

The selected journals were *Experts Systems with Applications*, *Journal of Cleaner Production*, *International Journal of Production Economics*, and *Industrial Engineering and Engineering Management*.

The search was performed by entering the keywords "green supplier evaluation" and "green supplier selection". The word "green" was then replaced by "environmental" and "ecologic". The word "supplier" was also replaced by "vendor". The words "evaluation" and "selection" were replaced by "assessment" and "qualification". A second set of keywords was then entered: "environmental criteria for supplier selection", "green multi-criteria decision making", and "green criteria for supplier selection".

The screening process consisted of looking for articles presenting a case of study in which a GSS problem was identified and a multi-criteria technique was used to solve the selection problem.

3.2. Second step: Review of articles

The articles were gathered and reviewed by obtaining information to establish a classification. The articles presented a SS case of study. The information obtained from the articles was then entered into software for easy management of the data.

3.3. Third step: Data entry using software

The classification categories used for the review were:

3.3.1. Year of publication

The search was limited to the period of time from 2007 to 2013. All the papers were classified according to their year of publication, in order to establish the progress in time.

3.3.2. Universities

The university in which the study was performed is important in order to understand the region in the planet that is working in this topic.

3.3.3. Journal Name

The journal category identifies the different disciplinary areas that contribute to the GSSP.

3.3.4. Case of study

The study provides a wide variety of applications in which a SS problem may exist. The case presents the different stages in an SS process, the technique, and the environmental criteria utilized.

3.3.5. SS Technique implemented

The multi-criteria technique used in the cases studies is one of the main objectives in the categorization. It is imperative to understand the main techniques utilized in the SS problem.

Table 1.
Papers considering GSS.

Year of publication	Number of papers considering GSS case studies
2007	2
2008	3
2009	6
2010	9
2011	9
2012	3
2013	2

Source: The authors

3.3.6. Green attributes employed in the selection

The case studies presented particular decision problems being solved. In most of the cases, the problem was related to a green supplier selection decision, for which attributes help evaluate the provided options. The attributes used in the GSS may vary depending on the type or product being supplied.

4. Material collection results

A total of 34 articles were found in the material collection process, and these were reviewed and grouped as is described in Section 3. This section shows the material collection results.

4.1. Year of publication

The distribution of the articles from 2007 to 2013 is shown in Table 1. It can be seen that 2010 and 2011 are the years with the highest number of publications.

4.2. Universities and academic departments

An additional way to present the information gathered in this review is to identify the university and academic department at which the first author works, providing work on the GSS topic.

Fig. 3 shows the universities at which the first authors conducted their research.

	University																														
Country	Chung Hua University	Tungan University	National Taipei University of Technology	Federal University of Sao Carlos	The Overseas Chinese Institute of Technology	National Tsing Hua University	Henan Polytechnic	Naresuan Phayao University	Tianjin Metallurgical Vocation-Technology Institute	Shandong University of Finance	Xi'an Polytechnic	Tianjin University	Science and Technology Beijing	Indian Institute of Delhi	Beijing Wuzi University	Tianjin University of Finance and Economics	Tungan University	Malaya University	Concordia University	National Taiwan University of Science and Technology	Aalborg University	Kocaeli University	Dalian University of Technology	Galatasaray University	Lung Hwa University of Science	National Institute of Technology	Greenwich	Total
China	0	0	0	0	0	0	4	0	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	1	0	0	0	13
Taiwan	1	1	2	0	1	2	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	10
India	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	3
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2
Turkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
Brazil	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Thailand	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Malasya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Canada	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	1	1	2	1	1	2	4	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1	1	34

Figure 3. Universities working on GSS
Source: The authors

The universities with the highest number of published articles are The Henan Polytechnic (4), located in China, followed by The University of Technology (2), National Tsing Hua University (2), and National Taipei Malaya University (2), all located in Taiwan, and then the Indian Institute of Delhi (2), located in India. The rest of the universities produced only one article. It can clearly be seen that China and Taiwan are the places where there are more research groups investigating aspects related to GSS techniques -representing 67.6% of this review- followed by India, Denmark, and Turkey with 20.5%, and finally, Brazil, Thailand, Malaysia, and Canada with 11.76%.

Table 2 presents the academic department within the universities that developed this type of research. It can be seen that the department with the most studies over these years is the Industrial Engineering Department, followed by the Environmental Management, and Energy and Science Departments.

4.3. Journals

The journal distribution shown in Fig. 4 identifies the different disciplinary areas contributing to the GSS process.

Table 2.
Academic department working on GSS

Department	Frequency
Industrial Engineering	6
Environmental Management	4
School of Energy and Science	4
Industrial Engineering and System Management	4
Management	3
Business Administration	2
Decision Sciences	2
School of Economics and Management	2
Department of Marketing	1
Engineering Design and Manufacture	1
Engineering Technology	1
International Trade	1
Mechanical Engineering	1
Metallurgic Engineering	1
School of Science	1

Source: The authors

Journal	Year of published							Total
	2007	2008	2009	2010	2011	2012	2013	
Experts Systems with Applications	0	0	1	1	2	1	0	5
Industrial Engineering and Engineering Management (IE&EM)	1	1	1	1	1	0	0	5
Journal of Cleaner Production	0	0	1	1	1	0	2	5
International Journal of Production Economics	0	0	0	2	1	0	0	3
Wireless Communications (WiCom)	1	1	0	0	0	0	0	2
Applied Soft Computing	0	0	0	0	0	1	0	1
Computers and Industry	0	0	0	0	1	0	0	1
Electronics, Communications and Control (ICECC)	0	0	0	0	1	0	0	1
Emerald Group Publishing Limited	0	0	1	0	0	0	0	1
I C on Automation and Logistics (AL)	0	0	0	0	1	0	0	1
I C on Supply Chain Management and Information Systems (SCMIS)	0	0	0	1	0	0	0	1
IC on Business Management and Electronic Information (BMEI)	0	0	0	0	1	0	0	1
IC on Machine learning and Cybernetics (MLC)	0	1	0	0	0	0	0	1
International Conference of management and Service Science (MASS)	0	0	1	0	0	0	0	1
International Conference on Mechanical and Electrionics Engineering (ICMEE)	0	0	0	1	0	0	0	1
International Conference on Signal Processin Systems (ICSPS)	0	0	1	0	0	0	0	1
International Conference on Systems, Man, and Cybernetics (SMC)	0	0	0	0	0	1	0	1
Internet Technology and Application	0	0	0	1	0	0	0	1
Supply Chain Management: an International Journal	0	0	0	1	0	0	0	1
	2	3	6	9	9	3	2	34

Figure 4. Journals with GSCM publications
Source: The authors

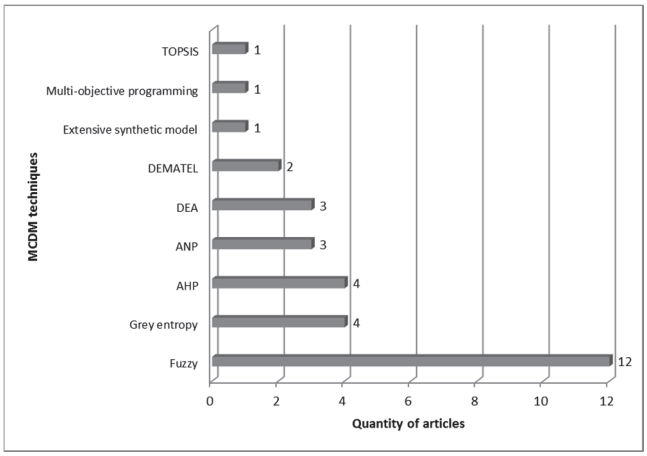

Figure 5. Multi-criteria techniques.
Source: The authors

There are three main journals identified in this literature review with the highest number of published articles on this topic: *Experts Systems with Applications*, *Industrial Engineering and Engineering Management* (IE and EM), and *Journal of Cleaner Production, all* with five published articles. The list continues with the *International Journal of Production Economics* with three published articles, followed by the *Wireless Communications* (WiCom) with two. The rest of the journals listed in the table have only one paper published on the topic. The information in this figure shows that the interest in green issues and environmental concern is being addressed in different areas.

4.4. Multi-criteria Techniques

There were 34 articles reviewed, and all but two considered a case study being applied where a SS problem was presented, and a MCDM technique was developed using traditional and green criteria in the selection process. Fig. 5 provides a summary of these techniques.

A total of 12 articles present a review using fuzzy logic models. A comparison of the GSS between the American, Japanese, and Taiwanese electronics industry in China is shown in [35]. The case of a printed circuit board manufacturer in Taiwan that seeks to implement GSCM is illustrated in [36]. A fuzzy multi-criteria decision problem approach with vague sets in an iron and steel company is shown in [37] and [38]. A new ranking method on the basis of fuzzy inference system (FIS) is applied in [27].

The next MCDM used was the Grey entropy model, which was in four papers: Chiou et al. [39] developed a model where subjectivity can be avoided in ascertaining weights of lower hierarchy factors. An improved grey correlative method applied in a previous publication is shown in [39] and [40]. An introduction of additional levels of analysis and application of grey entropy is presented in [41]. Finally, four papers are related to the use of Analytic Hierarchy Process (AHP) models [42-45].

4.5. Green attributes

In the traditional SCM, SS criteria consisted of the common qualities, cost and time, but due to the increased

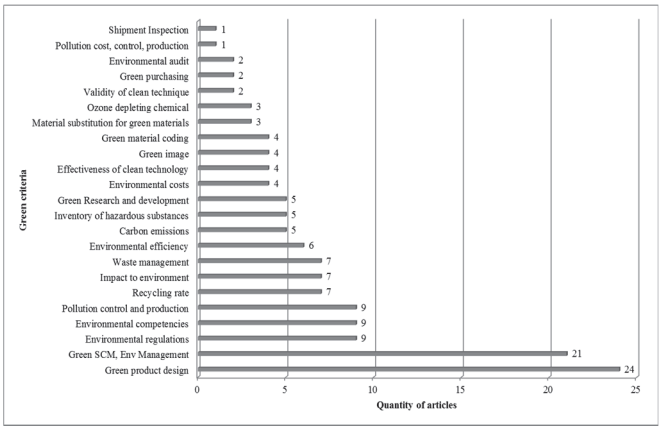

Figure 6. Green criteria
Source: The authors

awareness of environmental protection these are no longer important. Therefore, the traditional SSP incorporates green criteria in order to comply with environmental regulations, social consciousness, and industry performance.

From a total number of 34 published articles, 24 concurred that green product design is a criterion to be used when evaluating and selecting a supplier, 21 saw green supply management as being important, 9 environmental regulations, 9 environmental competencies, 9 pollution control and production, 7 recycling rate, 7 impact to the environment, 7 waste management, 6 environmental efficiency, 5 carbon emissions, 5 inventory of hazardous substances, and 5 green research and development. This can be seen in Fig. 6.

5. Analysis of the results and discussion

In this section, the key findings that resulted from the material collection are presented. The main goal of this study was to identify how GSS has evolved over recent years and which characteristics are discernible. Then, based on the review as well as the results, this section explains how the green criteria are useful in any GSS.

5.1. Analysis of publication distribution

There was a growing trend from 2007 to 2011 that showed an evolution in awareness regarding environmental impact issues. Based on the wider awareness of environmental concerns over the last decade, it is foreseen that research on the topic will continue to progress.

5.2. Analysis of environmental criteria in GSS

Environmental consideration of SS is a key competitive issue for large and medium-sized enterprises, and thus maintaining long-term relationships with these suppliers should be taken into account. De Boer et al. [17] proposed a knowledge-based system to evaluate the supplier's environmental performance, which can be sectioned into several categories: environmental costs, management competencies, green image, green design, environmental management system, and environmental competencies.

This section explores the broad environmental criteria of either quantitative or qualitative attributes with regard to environmental cost, production process, product, and management systems.

5.2.1. Environmental competencies

The percentage of companies that have established a GSC in order to incorporate ecological care is low. Nevertheless, there are companies that have a big concern for environmental issues and have actually established a plan to respond to regulations and social concern. In some cases the bigger the company, the greater the interest in integrating a GSC.

The development of environmental plan must include some important points in order for the response to be successful:

- Environmental impact assessments that define the current situation and areas that have opportunities.
- Environmental education and training, to provide information and develop environmental culture.
- Green design training, to increase design core groups' eco-engineering skills.
- Environmental policies and standards development, to establish an efficient operating system.
- Pollution prevention and control systems, to continuously improve and innovate product designs and manufacturing processes.
- Waste management systems implementation, to establish future re-use, recycling, and disposal of material.
- Strategic planning, monitoring, and reporting systems.

5.2.2. Green product design

One of the most important criteria in SSP is the capability for green design, which can promote product-oriented GSC implementation. According to Humphreys et al. [18], the strongest testament to the greening of international markets is the expanding number of companies seriously addressing environmental concerns as part of their product development process. A product is considered eco-friendly if it does not represent a threat to the environment when released into the air, water, or earth, either when it is in use or at the end of its life cycle. Green product design is extremely important because it is a key element in establishing a GSC. Green design can indicate the direction that each SC component will follow. Companies need to invest in design core groups and help to develop an understanding of how design decisions impact the products' entire life cycle.

5.2.3. Carbon emissions management

Carbon (CO2) emissions result from a variety of activities that humans undertake in their daily lives. Growing levels of anthropocentric CO2 emissions are known to cause global warming [20]. As the public becomes more aware of environmental issues and global warming, consumers will be asking more questions about the products they are purchasing. The term carbon footprinting refers to the total

amount of CO2 or greenhouse gases emissions an individual or organization is responsible for. Companies will have to expect questions about the state of their green manufacturing processes, their SC, their carbon footprint, and how they recycle. Luckily, CO2 emissions can safely be dealt with and predicted if a well-defined green design and manufacturing process is established within the company.

5.2.4. Energy/Resource consumption

Due to global competition, it is crucial for an enterprise to enhance its ability to improve energy utilization and efficiency through the enterprise's inner energy audit and energy management [21]. Energy conservation management projects promoted by the government, and energy audits have been undertaken in developed countries since the 1970s [22].

As shown by Zhang et al. [23], the case study detailed in this paper's main objective is to discover energy auditing and energy management problems in regions such as China. The case study reveals that if enterprises are unwilling to cooperate actively with the energy audit, then the government should improve the energy performance assessment system, increase capital investment, and develop energy-saving tax incentives.

All the current lean manufacturing methods, which have the primary objective of eliminating waste in a production process, are associated with energy and resource consumption. This attribute is really important, as can be seen in modern GSCs. When selecting a supplier, not only the traditional evaluation criteria is used, green criteria is also incorporated. In order to eliminate waste, there has to be better consumption of the current resources (raw materials, water, air, etc.,), as well as more consideration of the energy needed to manufacture a product.

5.2.5. Green material coding

ISO 11496 specifies a system for the uniform marking of products that have been fabricated from plastic materials. It intends to help identify plastic products for subsequent decisions concerning handling, waste, recovery, or disposal. These days, a common company practice is to incorporate the material specification code on a visible location on the part; this helps distinguish materials from a pile of products. There are companies that can handle a variety of plastic parts, and having the material code engraved in the component will easily help with the disposal of these parts at the end of their lives.

Material coding is also important when disposing of the products that have reached their end of their lives. It provides an immediate identification of hazardous and non-hazardous materials. Eveloy et al. [24] recommend that all lead-free materials, components, and boards should be assigned new part numbers to distinguish them from lead-based ones.

5.2.6. Management of hazardous substances

There is a serious-restricted use of hazardous substances during the production; therefore, companies have taken special interest in reducing the utilization of these substances and complying with environmental regulations. The International Electrotechnical Commission (IEC) set up the Hazardous Substance Process Management (HSPM) standard — namely, IECQ QC 080000 HSPM. As shown by Hsu and Hu [25], obtaining a certification helps companies mitigate risks associated with hazardous substances.

5.2.7. Waste management system

Waste is produced in all human activity; there is always something leftover. Therefore, the key point is to reduce the impact of this residue on the environment. In order to ensure the protection of the environment, a waste management system needs to be established. For example, all of the current lean manufacturing methods like SMED, Six Sigma, or Kaisen help companies achieve this reduction in operational costs and waste. For instance, according to Zúñiga-Ceron and Gandini-Ayerbe [26], the final disposal of sugar cane waste represents a huge environmental challenge. Therefore, the industry is looking for solutions such as the conversion of their residues into sub products to obtain economic gain, and at the same time reduce the environmental impact.

After the establishment of Waste Electrical and Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS), and Eco-design for Energy-using Products (EuP), directives have been passed by the European Union (EU), and GSCM has been adopted as a strategy by leading electronics companies, including Dell, HP, IBM, Motorola, Sony, Panasonic, NEC, Fujitsu, and Toshiba [27].

A proper waste management system may integrate the following:

- Green product design can define the easy disposal of the product at its end-of-life cycle.
- Reduce waste releases to water, land, or air by resource management consumption.
- Reuse of discarded waste products will help reduce generation of unnecessary material.
- Recycling materials will lower the waste rate.

5.2.8. Recycling

According to Yi and Wang [28], there are three types of reverse SC recycle models in developed countries:

1. Manufacturer Take-Back (MT). This recycling model requires that the manufacturer build an enormous recycling network at an excessive cost.
2. Retailer Take-Back (RT). This recycling model can effectively utilize the stronger marketing network of a retailer, but the manufacturer has to face some coordination problems with the retailer, such as recycle pricing.
3. Third Party Take-Back (TPT). This category includes companies that lack investment and knowledge to develop their own reverse logistic system. The companies outsource this requirement to a third party, requiring less effort from them.

5.2.9. Green purchasing

The purchasing department has become much more important due to the recent agile improvement of network

technology and economic globalization [29]. Buyers in an SC are in the ideal position to identify an environmental risk and formulate requirements for suppliers to meet. The purchasing department needs to be at the forefront of all the environmental regulations in order to maintain a close relationship with the engineering group developing the product. This will help eliminate mistakes or conditions that lead to selecting an incorrect supplier. Environmental standards in purchasing provide a basis for constructive dialogue with suppliers within a joint commitment to quality progress context, and should motivate suppliers to promote these activities with their own suppliers [30].

5.2.10. Green research and development

The technology, method, and tool research relating to a green product has also become important [31]. The different GSC approaches — green sourcing, green manufacturing processes, green design, and reverse logistics —together provide new sources of innovation and continuous improvement of current management systems. For instance, as shown by Chen [32], the printed circuit board construction process is currently migrating from traditional eutectic Pb-Sn alloy to different lead-free alloys. This replacement attempts to alleviate the problem of the Pb-Sn solder alloy, which is toxic. However, this does not change the component separation problem for reuse and/or disposal of these materials without harming the environment. This means that, regardless of implementing an action to reduce the impact of one material or practice, the action needs to be deeply explored in order to measure its future impact as well.

5.2.11. Green image

Enhancing a companies' image is one of the most common reasons for assuming a green strategy, and, according to Canal-Marques et al. [33], companies that invest in environmental efforts are able to improve their corporate image and develop new markets, as well as increase their competitive advantages. People's awareness has pushed companies to act and incorporate green practices in complying with environmental regulatory constrains for the purpose of gaining market profit. Companies that embrace the green environment concept with environmentally friendly products and packaging can charge relatively high prices for their products, and thus increase their products' differentiation advantages [34, 35].

5.2.12. Environmental Regulations

Suppliers who have acquired environmental management systems (EMS) certifications (ISO14001) can state that an organization has implemented a management system that documents the its environmental aspects and impacts, and has identified a pollution prevention process that is continually improved over time [34,35]. Having this certification helps companies acquire a green public image, looks after the environment, and confers external legitimacy [35]. Companies may also be able to use ISO 14001 to increase their internal efficiencies and create competitive advantage opportunities and economic benefits [36].

There are several reasons, as mentioned by Coglianese and Nash [37], why companies implement ISO 14001:

- It is the best external valuation and they improve their corporate reputation.
- They prove their social responsibility and commitment to the environment.
- They will have continuous improvement.
- It helps with and ensures the legality of compliance with environmental legislation.
- It is different from the competition.
- Its administration is easy and its implementation is promoted.
- It improves competition scores and is mandatory.
- It improves safety at work.
- It promotes growth.

6. Conclusions and further work

SC professionals are under pressure to build a successful SC strategy that will raise productivity and competitiveness, respond to demand variations and environmental regulations, while at the same time empower product innovation and promote continuous improvement. Several years ago, there was a lack of environmental care and social awareness, with no connection to investment and profitability. This is no longer the situation. Social concern about environmental issues and global warming is causing consumers to demand that the products they are purchasing go green. Companies are being questioned about how green their manufacturing processes and SCM are, and what they are currently doing to reduce their carbon footprint and tackle global warming.

This paper informed the reader of the following: that GSCM is being adopted; that green criteria are being incorporated within evaluation techniques; that selecting a supplier is an important decision. This is the case, not only with respect to providing the organization with the right products at the right cost, but also taking into consideration environmental performance by eliminating contaminants, and reducing the energy to produce the products, etc.

It could be worthwhile to undertake further research on topics such as how companies deal with balancing the different GSS practices and how this practice could be more effective.

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