

## Article

# Effect of Green Supply Chain Management Practices on Environmental Performance: Case of Mexican Manufacturing Companies

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**Abstract:** Managers implement several Green Supply Chain Management (GSCM) practices to improve sustainability and economic performance, such as environmental management systems (EMS), eco-design (ED), source reduction (SR) and attending to external environmental management (EEM) requirements; however, the relationship among them requires a deep study. This paper reports the case of the Mexican maquiladora industry, analyzing the main relationships among GSCM practices with environmental impact (EI) and environmental cost savings (ECS). The analysis reports three structural equation models (SEM) developed as simple, second-order, and mediating models. Those relationships are tested using 160 responses to a survey applied to the Mexican maquiladora industry and with partial least squares algorithms (PLS), where conditional probabilities for different scenarios in latent variables are also reported. Findings indicate that EMS has a direct effect on EI ( $\beta = 0.442$ ) and ECS ( $\beta = 0.227$ ), indicating that EMS reduces EI and cost associated with the production process; however, ED has no direct effect on EI ( $\beta = 0.019$ ) and ECS ( $\beta = 0.006$ ), and it can be due to the maquiladora nature as foreign companies focused on manufacturing and not to product design.

**Keywords:** green supply chain practices; Mexican maquiladora; environmental impact; causal analysis

**MSC:** 62H25; 62J05; 93E24; 62P12

## 1. Introduction

Modern companies adopt corporate practices based on environmental, social, and economic analysis [1]. With the incorporation of environmental responsibility into production systems, a new approach to supply chain management has arisen. It is named green supply chain management (GSCM), where consumers and governments demand that both production processes and products be environmentally friendly. Consequently, companies have identified and implemented environmentally sustainable practices into their supply chain (SC) systems.

GSCM refers to incorporating environmental thinking into SC management at all stages, including product design, material procurement, production process, packaging, delivery, and product end-of-life (EOL) management. By implementing a GSCM approach,

companies can successfully comply with environmental policies while simultaneously enhancing their environmental and financial performance and improving their corporate image [2]. Additionally, green SC systems positively impact cost reduction as green suppliers become more involved in environmental innovation [3]. Manufacturers must incorporate environmental variables in their strategic planning for a sustainable response to customers since they are increasingly environmentally conscious and exercise their power through purchased products.

Successful GSCM requires combining environmental thinking with resource optimization, environmental design, and the pursuit of sustainable development, thus controlling external pressures (customers, suppliers, and the government) and internal pressures (waste reduction, recycling, reusing, and energy consumption) [4]. As a response to such a challenge, GSCM relies on Environmental Management Accounting Practices (EMAP).

GSCM is commonly associated with high costs and few benefits, and sometimes, managers avoid investing in it [5]; however, unsuccessful GSCM is due mainly to the absence of organizational commitment and technical experience, a deficient organizational culture, resistance to change, and a lack of information and technology [6]. GSCM is a research topic across a variety of industrial sectors, and several reports appear in the literature; for example, Younis, et al. [7] associated GSCM practices (ecological design, green purchasing, environmental cooperation, and reverse logistics) with corporate performance (operational performance, environmental performance, economic performance), inverse logistics, and social performance. In turn, Green Kenneth, et al. [8] found that sustainable customer purchases do not significantly impact the environmental performance of SC systems but rather their economic performance. In addition, Aalirezai, et al. [9] analyzed the effects of GSCM practices on the environmental, operational, and economic performance of Iranian automotive companies and reported that GSCM positively promotes supplier performance.

## 2. Research Case Study

Despite the vast amount of literature on GSCM, this topic in the Mexican manufacturing industry remains little explored, even with the importance of its supply chain and this paper is focused on the maquiladora sector. A maquiladora is a subsidiary company established in Mexico, mainly focused on manufacturing activities and headquartered in another country. They are traditionally established on the border of Mexico with the United States of America to have closer proximity to their customers and take advantage of preferential tariffs due to free trade agreements between both nations [10].

According to the National Institute of Statistics and Geography [11] (INEGI, by its Spanish acronym), the maquiladora industry is key to the economic development of Mexico, and in December 2021, 5192 maquiladora companies that export 293,073 million USD and import approximately 238,847 USD millions. In the northern state of Chihuahua, there are 488 maquiladora industries that export and import 32,186 and 28,643 USD million, respectively. However, Ciudad Juárez, one of the leading industrial cities in Chihuahua, has 327 that import and export 27,841 and 22,689 million, respectively.

The flow of goods as raw material in the import process and of finished products that are exported from the Mexican maquiladora industry is very intense; furthermore, these logistic activities do not generate added value to the product, but they do generate many costs and a great environmental impact, which is why it deserves to be studied [12].

Currently, studies on the Mexican maquiladora industry have analyzed aspects associated with the internal supply chain and the application of manufacturing tools, such as just-in-time (JIT) and its impact on operational performance [13], and the benefits obtained from its implementation [14]; however, environmental aspects have been little studied. Authors such as Grineski, et al. [15] indicate that proof of this is the proximity of residential areas to industrial parks without assessing the risks involved, while Munguia, et al. [16] indicate the minor focus on the efficient use of energy in the maquiladora sector and Velázquez, et al. [17] indicate that sustainable practices are little studied in the Mexican industrial sector. This research aims to cover that gap, quantifying the effects of GSCM

practices on Mexican manufacturing companies' economic and environmental performance as an exploratory study.

In this paper, we measure the effects of four GSCM practices—*Environmental management system (EMS)*, *Ecological design (ED)*, *Source reduction (SR)*, and *External environmental management (EEM)*—and the relationship with *Environmental impacts (EI)* and *Environmental cost savings (ECS)*. Our research takes a similar study reported by Al-Sheyadi, et al. [18], which found a positive relationship among these variables. Findings from this research will support managers in identifying the variables that help them reduce negative environmental impacts and operating costs in the Mexican maquiladora industry.

The remainder of this article is organized as follows: in Section 2, we introduce a literature review and propose our research hypotheses. In Section 3, we discuss our research methods and materials. Section 4 offers a comparative analysis between the results reported by Al-Sheyadi, et al. [18] and those found in this research. In Section 5, we discuss our results. Finally, in Section 6, we propose our research conclusions.

### 3. Literature Review and Research Hypotheses

#### 3.1. Environmental Management Systems (EMS)

Increasing customer awareness has made environmental factors critical elements in corporate strategic planning. Nowadays, companies resort to environmental management practices integrated as an *Environmental management system (EMS)*. EMS under the ISO 14001 standards is a structured approach to addressing environmental issues in corporations. In other words, environmental management is now viewed as a methodology to operate orderly, assess the sustainability of their operations, and guarantee an environmentally friendly performance [19]. EMS integrates procedures, processes, policies, tasks, and guidelines for protecting and managing environmental performance and preventing risks. As a result, it becomes crucial for every organization to quantify the environmental impact in all its industrial activities, control and manage such impact, and increase its sustainable performance [20].

In environmental management, employee involvement is crucial because motivated, skilled, and well-equipped employees are proactive in making their company sustainable. They propose new ideas to managers, customers, and suppliers to help reduce their operations' adverse effects on the environment [21]. Organizational commitment is also critical to the success of EMS since managers help guarantee that their companies both invest in the necessary resources and implement the environmental programs necessary to ensure sustainability both in and out of the company [22]. To verify whether Mexican manufacturing companies rely on EMS, we study the following items [18]:

- Cross-functional cooperation
- Providing ongoing support from top management
- Regular maintenance of the production equipment
- Providing training to employees/managers in various environmental management areas
- Using an internal environmental program
- Using remanufacturing and recovery programs

#### 3.2. Environmental Cost Savings (ECS)

The economic performance of environmental programs is measured by how companies can reduce costs associated with material procurement, energy consumption, waste management, environmental penalties, technological and environmental management investments, and green certifications [23]. According to Porter and Van der Linde [24], cost reduction is achieved through environmental policies aimed at innovations that reduce the cost of final products, make efficient use of raw materials, and remove hazardous materials and processes, among others. To determine the degree to which Mexican manufacturing companies reduce their operational costs as a result of environmental management practices, we review the following items [18]:

- Decrease of fee for waste treatment

- Decrease of fee for waste discharge
- Decrease in energy consumption cost
- Decrease in material purchasing costs

Achieving cost savings implies relying on an *EMS* that implements environmental policies and assesses the performance of such policies concerning costs, energy consumption, raw material optimization, and waste management [25]. *EMS* assessments must be conducted in material procurement, manufacturing, distribution, and product development [26]. Furthermore, *EMS* must effectively reduce waste and energy consumption through environmentally friendly strategies [27]. To study the relationship between *EMS* and environmental costs, we propose the following research hypothesis:

**Hypothesis 1a (H1a).** *Environmental management systems have a positive direct effect on Environmental cost savings*

### 3.3. Environmental Impact (EI)

Every production operation has an environmental impact, constantly monitored to maintain environmental awareness and comply with government regulations [28]. The ISO 14001 standard defines environmental impact as any change to the environment—either positive or negative—resulting from any human activity. Environmental impact is measured through air emissions, wastewater discharges, solid waste discharges, and the use of hazardous and toxic materials [29]. *EMS* promotes sustainability in the SC system, from material supply, all manufacturing processes, and product EOL management [30] to eliminate pollutants. From this perspective, we measure environmental impact through the following items [18]:

- Reducing consumption of harmful materials
- Reduction of air emissions
- Reduction of water emissions
- Reduction of solid waste disposal
- Reduction of environmental accidents

*EMS* must achieve greater sustainability in organizations by reducing the environmental impact of the industrial operations along all the product stages, not only at the manufacturing stage [31]. To this end, *EMS* ought to have clear goals to improve environmental performance [32]; that is, it is essential to identify and assess the environmental impact of all corporate operations, set the necessary environmental control measures, and define the threshold values of the company's environmental policy [33]. From this perspective, we propose the second research hypothesis as follows:

**Hypothesis 2a (H2a).** *Environmental management systems have a positive direct effect on Environmental Impact.*

### 3.4. Ecological Design (ED)

Product design is of vital importance for product manufacturing since a deficient design compromises the sustainable development of companies [34]. *ED* consumes less energy, ensures easy recycling and recovery of components from used products, and entails a non-toxic production process [29]. In addition, as its primary goal, *ED* minimizes the negative *Environmental impacts* of a product at the design stage and avoids them at the manufacturing stage while simultaneously ensuring easy product maintenance and repair [35]. Finally, as the literature points out, successful *ED* entails commitment from managers and knowledge from suppliers. To study *ED*, we analyze the following items [18]:

- Using packaging and pallets which can be reused
- Increase the life cycle of the product
- Using a few, and reusable components

According to Kalyar Masood, et al. [2], *ED* reduces financial performance initially since costs initially increase and profitability decreases. From a similar perspective, Green

Kenneth, et al. [8] argue that *ED* is positively linked to the environmental performance of industries but is negatively associated with their economic performance due to the high costs of ecological raw materials. However, in the long term, costs can decrease as sales increase. Finally, according to Zhu, et al. [36], the ultimate goal of *ED* is to reduce the environmental impact of a product without adversely affecting its functionality and the costs of manufacturing it. To know the relationship between *ED* and the financial performance of Mexican manufacturing companies, we propose the third research hypothesis as follows:

**Hypothesis 3a (H3a).** *Ecological design has a positive direct effect on Environmental cost savings.*

*ED* is an approach to designing products with particular consideration for the *Environmental impacts* that such products may cause throughout their lifecycle [37], all without compromising attributes such as price and functionality [38]. *ED* must ensure easy component reuse and recycling, product recovery, remanufacturing, resource optimization, and disassembly of reusable components [39]. Likewise, *ED* must mitigate environmental risks at all stages of the product lifecycle, being proactive management of a product's performance in terms of energy consumption, resource allocation, pollution, and waste generation [40]. In this sense, our fourth research hypothesis reads as follows:

**Hypothesis 4a (H4a).** *Ecological design has a positive direct effect on Environmental impact.*

### 3.5. Source-Reduction (SR)

Growing industrialization and increased resource exploitation have led to more significant toxic waste discharges and higher amounts of pollutant emissions into the environment. Since this causes severe damage to both the environment and human health, manufacturing plants need to increase efficiency in their production processes. *SR* practices involve strategies for reducing waste, promoting clean materials and energy sources, reducing toxic emissions, and improving resource utilization [41]. Environmental responsibility is important at the manufacturing stage, including raw materials procurement. If raw materials contain toxic chemicals, the final products will be toxic [34], highlighting the importance of good communication with suppliers. To know the level of *SR* in Mexican manufacturing companies, we study the following items [18]:

- Use of recycled materials in production
- Reducing the variety of materials used in the production process
- Avoidance of harmful materials or components

The outcome of any business is to make profits while reducing costs, and it can be successfully achieved through *SR* strategies, such as material recycling and efficient packaging systems [42]. Moreover, avoiding toxic raw materials minimizes accidents and environmental hazards that ultimately lead to economic losses [43]. From this perspective, we propose the fourth research hypothesis as follows:

**Hypothesis 5a (H5a).** *Source reduction has a positive direct effect on Environmental cost savings.*

*SR* mitigates pollution as waste is reduced along with the *SC* system through recycling and re-utilization practices [44]. Additionally, *SR* aims to reduce energy use throughout the production process and minimize air and water pollution [45]. From this perspective, we propose the sixth research hypothesis as follows:

**Hypothesis 6a (H6a).** *Source reduction has a positive direct effect on Environmental impact.*

### 3.6. External Environmental Management (EEM)

The success of *EMS* also depends on external factors, such as social culture, government regulations, and customer-supplier relationships [46]. Suppliers contribute to organizational outcomes and goals by offering flexibility and supplying raw materials of

low cost, high quality, and environmentally friendly [47]. Similarly, customers are essential in *External environmental management (EEM)* to ensure clean production, offer ecological packaging alternatives, and increase social responsibility [48]. Both suppliers and end customers must play a role in any environmental development program put forward by manufacturers [39]; hence, they must be carefully selected. In this research, *EMS* is studied through the following items [18]:

- Including environmental considerations in the selection criteria for suppliers
- Achieving environmental goals collectively with our leading suppliers
- Providing suppliers with written environmental requirements for purchased items
- Providing customers with written environmental information related to our products
- Working with customers to develop a mutual understanding of responsibilities regarding environmental performance
- Conducting joint planning sessions, workshops, and knowledge sharing activities with suppliers to anticipate and resolve environmental-related problems

According to Zhu and Geng [49], manufacturers must adopt ecological strategies and environmental practices that integrate both suppliers and customers into the production process to reduce the environmental footprint of their products and services. Additionally, collaboration among manufacturers, suppliers, customers, and the government improves the ability of manufacturers to coordinate and streamline operations, which ultimately increases customer satisfaction and helps reduce SC costs [50]. That said, attaining such a degree of synergy entails commitment from all parties to increasing environmental performance, reducing waste, and saving costs [51]. In this sense, we propose the following hypothesis:

**Hypothesis 7a (H7a).** *External environmental management has a positive direct effect on Environmental cost savings.*

Manufacturers have become increasingly dependent on their suppliers, mainly because of outsourcing initiatives and environmental pressures from the government and society. To mitigate their environmental footprint and simplify logistic operations, manufacturing companies integrate customers and suppliers into their *EMS* [52]. In this sense, it is essential for manufacturing systems to evaluate suppliers concerning their ecological performance and then select them based on attributes such as recycling programs, energy-saving practices, compliance with environmental regulations, and environmental audit programs [52]. In manufacturing systems, the success of ecological operations depends greatly on the environmental management strategies of suppliers and their ability to generate ecological innovations [53]. In this sense, the eighth research hypothesis of this work reads as follows:

**Hypothesis 8a (H8a).** *External environmental management has a positive direct effect on Environmental impacts.*

### 3.7. Collective GSCM (CGSCM)

In this research, we take the study of Al-Sheyadi, et al. [18] and seek to compare our findings with those reported by the authors. However, besides studying variables *EMS*, *ED*, *SR*, and *EEM* individually, we also merge them into one new variable, *Collective GSCM (CGSCM)*. As a result, we propose other hypotheses for both a second-order model (Model B) and a mediation model (Model C). Researchers claim that *GSCM* has, or at least intends to have, an impact on the environmental performance of industries. Similarly, Laari, et al. [54] and Yu, et al. [55] claim that *GSCM* must be a part of the corporate competitive strategy to guarantee compliance with environmental regulations. Finally, Lee and Kim [56] point out that, to mitigate negative *Environmental impacts*, manufacturers should pay as much attention to internal *GSCM* as to external *GSCM*. In this sense, we propose the following research hypotheses:

**Hypothesis 1b (H1b).** *Collective GSCM has a positive direct effect on Environmental impact on a second order model.*

**Hypothesis 1c (H1c).** *Collective GSCM has a positive direct effect on Environmental impact on a mediator model.*

For Rezende, et al. [57], green innovations always positively impact long-term financial performance. Additionally, Yu, et al. [58] and Li, et al. [59] point out that integrating customers and suppliers in EMS improves communication and reduces costs. Finally, according to Feng, et al. [60], GSCM can contribute to cost savings if companies pay close attention to those operational and environmental performance aspects that can potentially improve their corporate social image. In this sense, we propose the following research hypotheses:

**Hypothesis 2b (H2b).** *Collective GSCM has a positive direct effect on Environmental cost savings on a second order model.*

**Hypothesis 2c (H2c).** *Collective GSCM has a positive direct effect on Environmental cost savings on a mediator model.*

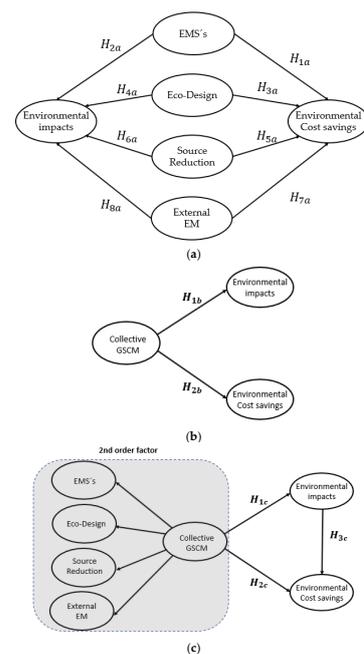
Undoubtedly, the reduction of EI in a productive process avoids administrative sanctions by governmental agencies to industries, which represents a decrease in ECS. In the same way, the reduction in pollutants emissions into the water, air and soil, avoids having to carry out special treatments that can be costly, so the following hypothesis is proposed:

**Hypothesis 3c (H3c).** *Environmental impact has a positive direct effect on Environmental cost savings.*

Finally, according to Feng, et al. [60], EI is a mediating variable between CGSCM and ECS and this is because a reduction in EI is a consequence obtained from the CGSCM application in the productive process, which is translated into ECS. Consequently, our last research hypothesis can read as follows:

**Hypothesis 3d (H3d).** *Environmental impact has a mediator effect in the relationship between Collective GSCM and Environmental cost savings.*

Figure 1 illustrates the research hypotheses discussed in this section.



**Figure 1.** Proposed hypotheses. (a) Simple model; (b) Second order model; (c) Mediator model.

## 4. Methodology

The research methodology used to test and validate the hypotheses comprises six stages, thoroughly discussed below.

### 4.1. Survey Development

We used the questionnaire proposed by Al-Sheyadi, et al. [18], divided into three sections. The first section includes demographic questions. The second section comprises 18 five-point Likert items to assess GSCM practices among companies through four variables *SR* (three items), *ED* (three items), *EMS* (six items), and *EEM* (six items). Finally, the third section assesses environmental performance through nine five-point Likert items and two variables: *EI* (five items) and *ECS* (four items).

### 4.2. Data Collection

The data is collected from the Mexican manufacturing industry because it can be easily accessed. Moreover, this sector works under international SCs and relies on a wide range of green practices due to their international customer's requirements. Support is requested from the Manufacturing, Maquiladora and Export Service Industry (IMMEX) Association established in Ciudad Juarez (Mexico) to identify potential respondents. The interview is focused on managers, supervisors, and production engineers who have at least one year of experience in the current position they hold, and for this reason, the sampling method is stratified.

An e-mail is sent to potential respondents from September to November 2019 to arrange a date and time to schedule the interview. At the end of the interview, they are asked for other colleagues they know and meet the established principles of inclusion, continuing with a snowball sampling. Although the research objective had been explained to responders via e-mail, it was again explained to them in person, letting them know that their answers were anonymous and for academic and scientific use.

Not all the interviews were conducted in the first established appointment due to responders' multiple tasks associated with their job positions. If, after three attempts, the interview could not be carried out, this case is omitted.

### 4.3. Data Capture and Screening

The collected data were registered in a database using SPSS 24<sup>®</sup> to be screened and analyzed. The screening process comprised the following steps, as proposed by Hair, et al. [61]:

1. Find the standard deviation of each responded survey to check for non-response bias.
2. Identify missing values in each survey and replace them with the median value. Discard a survey if it contains more than 10% of missing values.
3. Identify outliers by standardizing item values and replacing them with the median value.

### 4.4. Latent Variable Validation

We calculated the coefficients proposed by Kock [62] to validate the latent variables proposed in the Proposed models. These coefficients determine parametric predictive validity, internal validity, convergent validity, collinearity among latent variables, and non-parametric predictive validity for each latent variable.

### 4.5. Structural Equation Model

The hypotheses depicted in Figure 1 were tested with the structural equation modeling (SEM) and partial least squares (PLS) techniques using WarpPLS 7<sup>®</sup> software. To validate the model, we calculated a series of model fit and quality indices, as proposed by Kock [63], which included Average Path Coefficient (APC), Average R-squared (ARS), Average Adjusted R-Squared (AARS), Average block VIF (AVIF), Average Full Collinearity VIF (AFVIF), and Tenenhaus GoF (GoF). Models passing the efficiency and quality tests

could be interpreted by analyzing the effects between variables. The direct effects were used to statistically validate the research hypotheses proposed in Figure 1.

Latent variables that were successfully validated were integrated into their corresponding models for subsequent analysis. Each relationship between two variables was measured by a standardized  $\beta$  value to statistically test the null hypothesis ( $H_0: \beta = 0$ ) against the alternative hypothesis ( $H_1: \beta \neq 0$ ) at a 95% confidence level [64]. Additionally, each dependent variable was associated with an  $R^2$  value.

In addition to the direct and indirect effects measured in the mediator model in Figure 1c to compare with Al-Sheyadi, et al. [18], the Sobel test is used to measure the mediator effect, which integrates the coefficients of the regressions and their standard errors [65], and classifies it as total or partial.

4.6. Sensitivity Analysis

Probabilities of occurrence of latent variables are discussed in terms of high probability (+) and low probability (-). Since the PLS technique is based on standardized values, a high probability of occurrence comprises standardized values  $> 1$ , whereas a low probability of occurrence comprises standardized values  $< -1$ . Probabilities of occurrence can be of three types:

1. Probability for isolation occurrence. It is when a latent variable occurs in isolation in high or low scenarios.
2. Probability for simultaneous occurrence. It is when two variables occur conjointly in a combination in their high or low scenarios and can be represented by  $(X_d \cap X_i)$ .
3. Conditional probability. It is when a dependent variable has occurred, given that an independent variable has occurred in its low or high scenario and is represented by  $(P(X_d/X_i))$ . where:  $X_d$  represents a latent dependent variable  $X_i$  represents an independent latent variable.

5. Results

5.1. Sample Description

We collected 221 complete surveys. After careful data screening, 61 of these questionnaires were removed; hence, the analysis accounted for 160 reliable questionnaires. Table 1 summarizes the sample distribution. As shown in Figure 1, the automotive industry was the most surveyed, representing 42.3% of the sample. It was then followed by the medical industry, with 33 surveys (21.1% of the sample). As regards job positions, most of the sample comprised engineers and managers.

Table 1. Industrial sector vs. job position.

Job Position	Industrial Sector *										Total
	1	2	3	4	5	6	7	8	9	10	
Engineer	30	2	5	3	1	0	17	1	1	7	67
Manager	13	0	3	5	0	1	3	1	0	5	31
Supervisor	12	0	0	3	1	0	4	0	0	4	24
Other	5	0	0	4	1	0	6	0	1	4	21
Technician	6	0	0	1	0	1	3	0	4	2	17
Total	66	2	8	16	3	2	33	2	6	22	160

\* 1 Automotive; 2 Aeronautic; 3 Electric; 4 Electronic; 5 Logistics; 6 Machining. 7 Medical; 8 Rubber and Plastics; 9 Textiles and apparel; 10 Other.

Table 2 summarizes the characteristics of the sample concerning years of work experience and company size. As observed, 70% of the sample (113 participants) have more than five years of experience in their current positions, whereas 76.25% (122) of the surveyed companies have more than 1000 workers each.

**Table 2.** Years of experience and number of employees.

Years of Experience	Number of Employees						Total
	<50	51–300	301–1000	1001–5000	5001–10,000	>10,000	
>1 & <2	2	2	3	5	2	3	17
≥2 & <5	1	1	2	12	9	5	30
≥5 & <10	2	3	9	16	5	13	48
≥10	5	3	5	28	8	16	65
Total	10	9	19	61	24	37	160

5.2. Latent Variable Validation

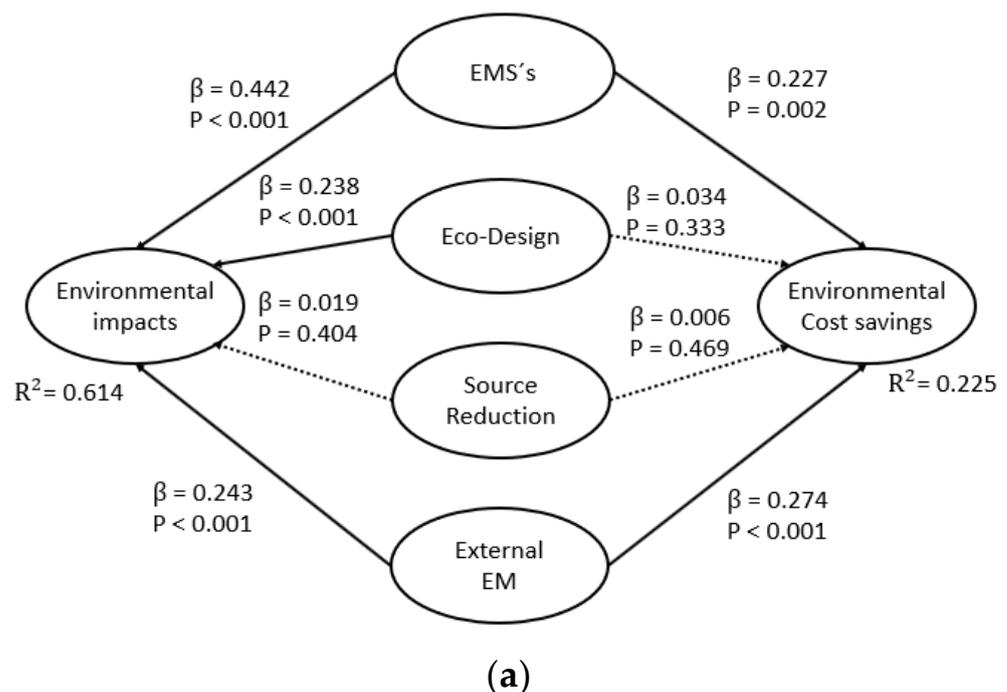
Table 3 lists the latent variable coefficients for model a, b and c. All the latent variables were integrated into their corresponding models since they all showed enough predictive validity, convergent validity, and no signs of collinearity.

**Table 3.** Latent variable coefficients.

Indexes	Best If	a. Simple model					b. Second-order model				c. Mediator model		
		EMS	ED	SR	EEM	EI	ECS	CGSCM	EI	ECS	CGSCM	EI	ECS
R <sup>2</sup>	>0.2					0.614	0.225		0.61	0.194		0.61	0.231
Adjusted R <sup>2</sup>	>0.2					0.604	0.205		0.607	0.189		0.607	0.221
Composite reliability	>0.7	0.907	0.849	0.819	0.922	0.923	0.927	0.881	0.923	0.927	0.881	0.923	0.927
Cronbach's alpha	>0.7	0.876	0.734	0.704	0.898	0.889	0.895	0.819	0.889	0.895	0.819	0.889	0.895
AVE	>0.5	0.62	0.653	0.531	0.662	0.749	0.762	0.651	0.749	0.762	0.651	0.749	0.762
VIF	<5	2.517	1.513	1.92	2.381	2.63	1.317	2.365	2.448	1.294	2.365	2.448	1.294
Q <sup>2</sup>	>0					0.617	0.227		0.609	0.196		0.609	0.231

5.3. Structural Equation Models

All the model fit and quality indices showed acceptable values, as proposed by Kock [62]. As a result, the models were interpreted. Figure 2 depicts the tested models. Solid line arrows represent statistically significant relationships between two latent variables, whereas dotted line arrows indicate statistically non-significant relationships, according to their corresponding p and β values. Table 4 lists the estimates used to validate the model.



**Figure 2.** Cont.

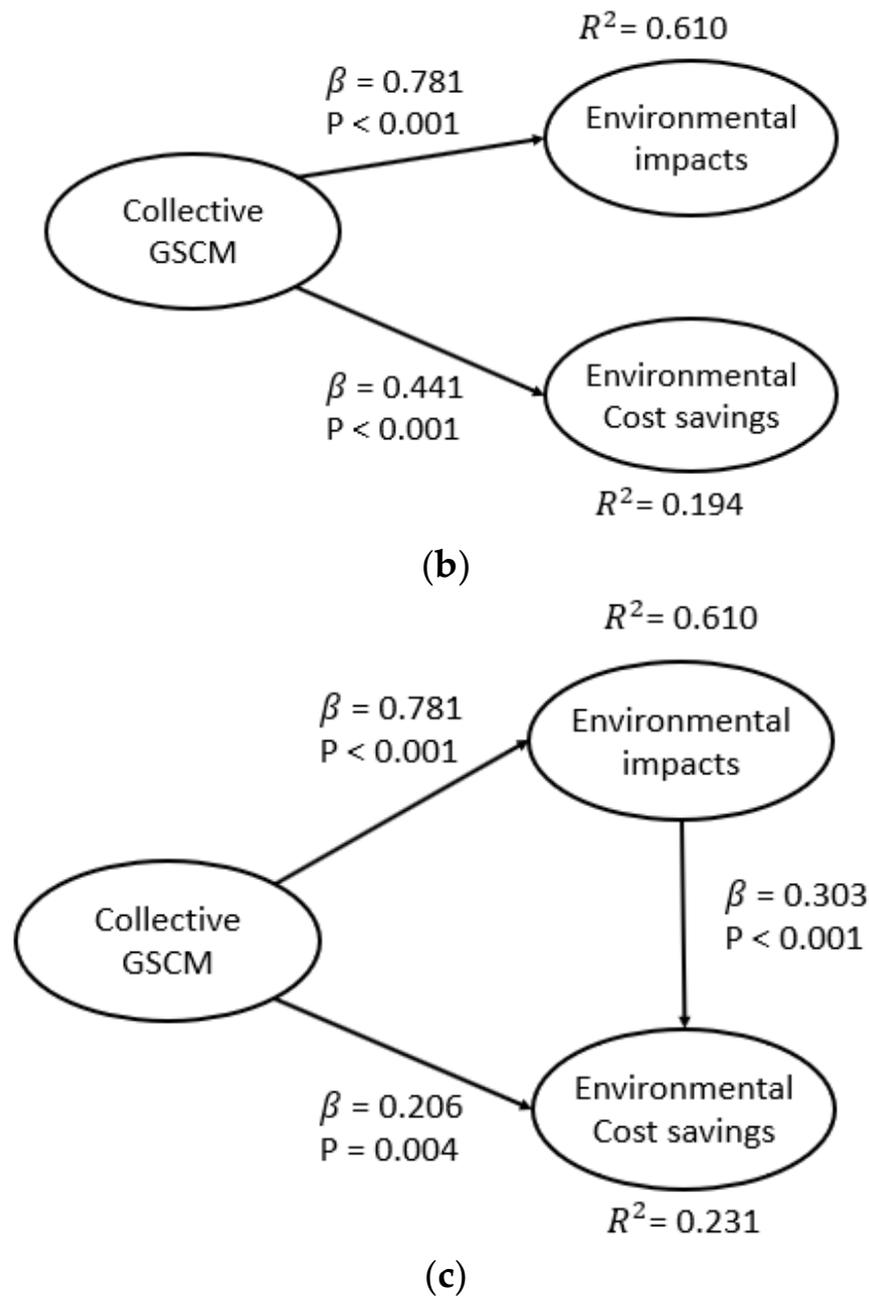


Figure 2. Evaluated models. (a) Simple model; (b) Second order model; (c) Mediator model.

Table 4. Model fit and quality indices.

Index	Best if	Model a		Model b		Model c	
		Value	p-Value	Value	p-Value	Value	p-Value
APC	$p\text{-value} < 0.05$	0.185	0.004	0.611	$<0.001$	0.43	$<0.001$
ARS	$p\text{-value} < 0.05$	0.419	$<0.001$	0.402	$<0.001$	0.42	$<0.001$
AARS	$p\text{-value} < 0.05$	0.404	$<0.001$	0.398	$<0.001$	0.414	$<0.001$
AVIF	$\leq 5$	1.858		NA		2.512	
AFVIF	$\leq 5$	2.046		2.036		2.036	
GoF	$\geq 0.36$	0.527		0.538		0.55	

Table 5 compares the direct effects found in our models and those reported by Al-Sheyadi, et al. [18]. The last column of the table indicates which relationships are similar across the two studies in terms of magnitude. As can be observed, only six of the 11 relationships share similarities. Such findings are further addressed in Section 5.

**Table 5.** Comparison of the direct effects of the first-order model.

Model	Hi	Relationship	Our Model	Al-Sheyadi, et al. [18]	Similarity
			$\beta$ -Value	$\beta$ -Value	
a	H1a	EMS→ECS	0.227 **	0.226 **	Yes
	H2a	EMS→EI	0.442 **	0.380 **	Yes
	H3a	ED→ECS	0.034 ‡	−0.018 ‡	Yes
	H4a	ED→EI	0.238 **	−0.151 *	No
	H5a	SR→ECS	0.006 ‡	0.596 **	No
	H6a	SR→EI	0.019 ‡	0.543 **	No
	H7a	EEM→ECS	0.274 **	0.01 ‡	No
	H8a	EEM→EI	0.243 **	0.01 ‡	No
b	H1b	CGSCM→EI	0.781 **	0.648 **	Yes
	H2b	CGSCM→ECS	0.441 **	0.589 **	Yes
c	H1c	CGSCM→EI	0.781 **	0.563 **	Yes
	H2c	CGSCM→ECS	0.206 **	0.159 *	Yes
	H3c	EI→ECS	0.303 **	0.617 **	No

\*\* With statistical significance at 99% confidence, \* With statistical significance at 95% confidence, ‡ no statistical significance at 95% confidence.

An indirect effect between CGSCM and ECS is observed through EI as a mediator, which is statistically significant at 0.237 ( $p < 0.001$ ), generating a total effect of 0.781 between both variables. The EI importance as a mediator in the relationship between CGSCM and ECS is ratified by the Sobel test, which value is  $Z = 3.729$  ( $p = 0.0001978$ ), indicating a partial mediation since the direct relationship is also statistically significant, and that proof H3d.

Table 6 summarizes the results from the sensitivity analysis for models a, b and c. Such results indicate the probability of two latent variables appearing isolated from one another, conjointly or conditionally. The results are also associated with high and low probability values.

**Table 6.** Sensitivity analysis.

Model	From	To		ECS		EI	
		Level	Level	+	−	+	−
			0.219	0.106	0.231	0.15	
a	EMS	+	0.206	& = 0.087 If = 0.424	& = 0.006 If = 0.030	& = 0.113 If = 0.545	& = 0.000 If = 0.000
		−	0.163	& = 0.006 If = 0.038	& = 0.044 If = 0.269	& = 0.000 If = 0.000	& = 0.081 If = 0.500
a	ED	+	0.194	& = 0.075 If = 0.387	& = 0.013 If = 0.065	& = 0.087 If = 0.452	& = 0.000 If = 0.000
		−	0.156	& = 0.06 If = 0.040	& = 0.031 If = 0.200	& = 0.019 If = 0.120	& = 0.069 If = 0.440
a	SR	+	0.181	& = 0.081 If = 0.448	& = 0.019 If = 0.103	& = 0.106 If = 0.586	& = 0.013 If = 0.069
		−	0.188	& = 0.006 If = 0.033	& = 0.031 If = 0.167	& = 0.000 If = 0.000	& = 0.087 If = 0.467
a	EEM	+	0.206	& = 0.100 If = 0.485	& = 0.006 If = 0.030	& = 0.119 If = 0.576	& = 0.000 If = 0.000
		−	0.206	& = 0.000 If = 0.000	& = 0.037 If = 0.182	& = 0.000 If = 0.000	& = 0.100 If = 0.485
b,c	CGSCM	+	0.175	& = 0.087 If = 0.500	& = 0.006 If = 0.036	& = 0.100 If = 0.571	& = 0.000 If = 0.000
		−	0.194	& = 0.000 If = 0.000	& = 0.044 If = 0.226	& = 0.000 If = 0.000	& = 0.119 If = 0.613
c	EI	+	0.231	& = 0.094 If = 0.405	& = 0.019 If = 0.081		
		−	0.15	& = 0.000 If = 0.000	& = 0.044 If = 0.292		

a. Simple model b. Second order model, c. Mediator model.

## 6. Discussion of Results

### 6.1. Model A: Simple Model

We sought to determine Mexican manufacturing companies' degree of environmental commitment through the SEM results, and in this sense, we found a clear trend toward environmental performance improvement. As Hernandez [66] points out, in 1990, the industrial focus was usually on economic growth, industrial expansion, and international commerce, without special consideration for the environment or the consequences of environmental degradation. Such assertion is supported by Schatan and Castilleja [67], who later studied the environmental problems in northern Mexico and their relationship with the corporate strategies of northern Mexican manufacturing companies. The authors found that most studied manufacturing plants lacked environmental policies or rarely applied environmental strategies.

Most of the hypotheses proposed in the simple model are statistically significant. For instance, the model confirms that investments in *EMS* have positive direct effects on *ECS* (**H1a**,  $EMS \rightarrow ECS = 0.227$ ). In other words, manufacturing companies committed to implementing and following environmental management procedures gain remarkable benefits in cost savings through energy-saving and waste reduction strategies. These results coincide with Kadlecová, et al. [68] on industries from the Czech Republic, where the cost of energy saved was reduced, and that similarity is because all of them are also companies of foreign origin, as occurs with Mexican maquiladoras.

The SEM results also confirm that investing in *Environmental management systems* directly affects the *Environmental Impact* that manufacturers cause (**H2a**,  $EMS \rightarrow EI = 0.442$ ). As manufacturing companies invest in cleaner production processes, they rapidly minimize pollutant emissions from their processes. These findings coincide with Zerlentes, et al. [69], that point out that the manufacturing industry entails opportunities for environmental agencies and ministries to improve the relationship between industrial infrastructure and natural ecosystems by understanding the indirect effects of economic development on the environment. Similarly, the authors claim that industrial development in manufacturing regions across Mexico carries critical environmental costs, which are not yet considered when developing production strategies.

However, the existence of *EMS* has been shown to minimize the environmental impact, as pointed out by Tarbeev, et al. [70] in the glass industry, Jafari and Lotfi Jalalabadi [71] in the oil industry in the Persian Gulf and Mohammedi and Teymouri [72] in the Zinc extractive industry in Iran.

Our findings indicate that *ED* cannot be directly associated with Environmental cost savings ( $ED \rightarrow ECS = 0.034$ ), even though previous research has demonstrated that recycled material and lightweight and straightforward packaging minimize environmental costs [73]. Such results might be explained because Mexican manufacturing companies are usually subsidiaries of other companies. Hence, they merely perform assembly operations for products designed or eco-designed by the parent company. From this perspective, the effects of *ED* on *ECS* are rather indirect. As the results from the sensitivity analysis demonstrate,  $ED^+$  leads to  $ECS^+$  in 0.387 of probability, whereas  $ED^-$  favors  $ECS^-$  in 0.200. In conclusion, managers must pay close attention to corporate *ED* strategies and policies.

This research provides enough statistical evidence of a positive direct relationship between *Ecological design* and *Environmental Impact* ( $ED \rightarrow EI = 0.238$ ). The sensitivity analysis results are consistent with those from the SEM, because  $ED^+$  leads to  $EI^+$  with a probability of 0.452, whereas  $ED^-$  lead to  $EI^-$ .

Such results imply that Mexican manufacturing companies acknowledge the importance of *ED* for reducing the *EI* in manufacturing processes, even though *ED* is not directly associated with *ECS*. Our results coincide with Bamba and Murtagh [74], who indicate that *ED* facilitates the recycling process and reverse logistics activities, reducing *EI* when sustainability is planned from design.

The role of *SR* is worth particular attention. Contrary to Al-Sheyadi, et al. [18], we did not find any statistically significant direct effect between *ECS* and *EI* in the maquiladora

industry. Once more, such results are due to the Mexican maquiladora nature, where manufacturers take no part in *ED*, material procurement, or material selection decisions, which parent companies instead make. However, managers in maquiladora companies acknowledge that material management, waste management strategies and clean energy usage notably improve the lifecycle of processes and products [75].

Such awareness is reflected in sensitivity analysis results because the conditional probability that occurs  $ECS^+$  given  $SR^+$  is 0.448,  $ECS^-$  given  $SR^-$  is 0.167,  $SR^+$  given  $EI^+$  is 0.586 and  $SR^-$  given  $EI^-$  is 0.467. These results agree with the report of Yu and Li [76] when analyzing the waste generated in an industrial kitchen, where activities associated with waste sorting decreased the negative impacts on the environment.

In contrast with the study of Al-Sheyadi, et al. [18], we found that  $EEM^+$  can be statistically and positively associated with  $ESC^+$ . Given the non-statistical direct relationship between the last two variables and *SR*, such results might be surprising; however, according to the findings from the sensitivity analysis, *EEM* has a positive indirect relationship with *ECS* and *ED*. Such results can be explained once again by the fact that the status of Mexican manufacturing companies as subsidiaries ties them to decisions made in corporate headquarters. From this perspective, parent companies act as customers of manufacturing subsidiaries. Even though the social culture in Mexico does not encourage *EMS*, government regulations and customer-supplier relationships enhance this symbiotic relationship.

The relationship between manufacturing subsidiaries and parent companies depends on the former's ecological performance. Parent companies may select their subsidiaries concerning their environmental attributes, such as recycling programs, energy consumption patterns, compliance with environmental regulations, and environmental audit programs. In this sense, our model indicates that *EEM* has positive effects on both *ECS* and *EI*, and that agrees with Liu, et al. [77] and Zheng, et al. [78], which indicate the supplier importance in *EI* and *ECS*. According to the sensitivity analysis, *EEM* favors *ECS* and  $EI^+$ , because  $P(ECS^+ / EEM^+) = 0.485$  and  $P(EI^+ / EEM^+) = 0.576$ . Such results indicate that Mexican regulations, specifically environmental audits, promote increasing environmental awareness in manufacturing systems.

## 6.2. Model B: Second-Order Model

The second-order model merges latent variables *EMS*, *ED*, *SR*, and *EEM* into a new latent variable, known as *Collective GSCM (CGSCM)*. Consequently, the model proposes a new set of hypotheses to study the relationships between *GSCM*, *ECS*, and *EI* and compare it with Al-Sheyadi, et al. [18]. According to the analysis, *CGSCM* can positively affect *ECS* and *EI*; in other words, by integrating environmental thinking (*ED*, material management, and supplier management) into the production process, manufacturers reduce their environmental footprint, and that means a reduction in waste, energy use, raw material costs, pollutant emissions, and environmental hazards.

Findings obtained in the Mexican maquiladora industry agree with the report by Al-Al-Sheyadi, et al. [18], since both models are statistically significant, and with the report by Qin, et al. [79], who indicates that a good industrial allocation and suppliers identification help to reduce costs and environmental impacts since it reduces transportation and logistics operations. Those relationships among *CGSCM*, *ECS*, and *EI* are confirmed by sensitivity analysis values and conditional probabilities, in where  $P(ECS^+ / CGSCM^+) = 0.500$  and  $P(ECS^- / CGSCM^-) = 0.226$ . In addition,  $CGSCM^+$  cannot be associated with  $ECS^-$  since  $P(ECS^- / CGSCM^+) = 0.036$ , indicating that internal and external environmental programs always are associated with economic benefits, and Mexican managers need to understand that.

We also found that *CGSCM* always reduces the negative *Environmental impacts* in the Mexican maquiladora companies since  $P(EI^+ / CGSCM^+) = 0.57$  and  $P(EI^- / CGSCM^-) = 0.613$ . Managers must pay close attention to the multiple dimensions of *CGSCM*, especially to the *EMS*, since the direct effect is the bigger. Finally, we also found that  $CGSCM^+$  can never be

associated with  $EI^-$ , whereas  $CGSCM^-$  is associated with  $EI^+$ . In both cases, the probability of occurrence is 0, indicating that  $CGSCM$  always reduces  $EI$  in the production process.

### 6.3. Model C: Mediating Model

The third model considers the same relationships as the second-order model. However, the mediating model merely explains the mediating effects of  $EI$  on  $ECS$ . According to the analysis results, the relationship between  $CGSCM$  and  $EI$  ( $CGSCM \rightarrow EI = 0.781$ ) is the most important since 61.0% of the variance in  $EI$  ( $R^2 = 0.610$ ) can be explained. Additionally, 23% of the variance in  $EC$  is explained by both  $EI$  ( $R^2 = 0.140$ ) and  $CGSCM$  ( $R^2 = 0.091$ ). Such results demonstrate that  $EI$  plays a higher role than  $CGSCM$  in  $ECS$ . In other words, to reduce costs while preserving the environment, maquiladora companies must first properly integrate green practices into  $CGSCM$  to reduce  $EI$  and ultimately achieve  $ECS$ .

Moreover, even though the direct effect of  $CGSCM$  on  $ECS$  is only 0.210, the relationship between both latent variables is much stronger because of the mediating effect occurring through  $EI$  (0.227). Consequently, the total effect is 0.437. Finally, findings from the sensitivity analysis indicate that as pollutant emissions and waste decrease, economic performance increases ( $P(ECS^+ / EI^+) = 0.405$ ). Conversely, if goals in  $EI$  and  $ECS$  are not reached, economic performance decreases ( $P(ECS^- / EI^-) = 0.292$ ).

## 7. Conclusions

Manufacturing companies are open systems that respond and evolve concerning customer demands, government regulations, and supplier performance. Hence, to comply with today's often strict environmental regulations in products and processes, a manufacturer's strategy must be developed from a  $GSCM$  approach. To this end, we take the research of Al-Sheyadi, et al. [18] and perform a similar study in the Mexican manufacturing industry. In this context, this research analyzes the effects of four leading  $GSCM$  practices—*Environmental management systems*, *Source reduction*, *Ecological design*, and *External environmental management*—on environmental impact and *Environmental cost savings*. Our results from the model analyses allow us to propose the following conclusions:

Investments in *Environmental management systems* lead to notable improvements in terms of *Environmental cost savings*. Environmental management policies are profitable as they guarantee reductions in energy use and waste management costs. Similarly, support for *Environmental management systems* reduces the negative *Environmental impacts* of manufacturing processes as production processes become cleaner.

Manufacturing subsidiaries underestimate the value of *Ecological design* as a tool for generating *Environmental cost savings*. However, this phenomenon might be explained because product specifications are established by parent companies only, which act as clients of manufacturing subsidiaries. In this research, the relationship between *Ecological design* and *Environmental impacts* is much clearer, which might be explained by the fact that manufacturing companies are much more aware of environmental policies and regulations for air emissions, water, and soil discharges.

The effects of *Source reduction* on both *Environmental cost savings* and *Ecological design* are not significant. This phenomenon can be explained by the fact that manufacturing subsidiaries in Mexico only perform assembly operations, and consequently, subsidiary company managers do not take part in decisions on material procurement.

Finally, perhaps one of the essential conclusions of this research is that even though Mexican manufacturing subsidiaries do not implement all the  $GSCM$  practices, they remain aware of the benefits of waste reduction and resource optimization strategies. Moreover, the relationship between these manufacturing companies and other actuators, such as government regulations, social environment, and customer-supplier relationships, enhances environmental sustainability. As social awareness of environmental preservation evolves positively, the ecological performance of Mexican manufacturing subsidiaries will have the potential to become a competitive advantage and become a definite aspect for parent companies to associate with them.

## 8. Limitations and Future Research

The information analyzed in this research was obtained from September to November 2019; however, in March 2020 in Mexico, many activities in the maquiladora industry were suspended due to the COVID-19 pandemic and that significantly affected the supply chains behavior, where managers and decision-makers were no longer only on environmental and economic sustainability, but also to preserve the health for their workers, which is a limitation in this report. For this reason, future research is intended to carry out the study again to identify differences regarding the industrial implications that have been had and to carry out transversal analyses, including aspects associated with social sustainability.

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