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Multidimensional scale for assessing the determinants of success of green information systems on organizational performance

Escala multidimensional para evaluar los determinantes del éxito de los sistemas de información verdes en el rendimiento organizacional

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Abstract

Environmental stewardship has become a relevant issue in the manufacturing industry, as the absence of environmental stewardship can cause irreparable havoc. This study aimed to develop a scale to assess green information systems, environmental strategies, and organizational performance in the manufacturing sector. 99 valid questionnaires were

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administrated to managers of Mexican manufacturing enterprises. The methodology used for the validation of the proposed scale was done in two stages: an exploratory factor analysis to confirm its theoretical structure and a confirmatory factor analysis to statistically validate it. The results indicate that the proposed scale proved to be adequate to measure the described phenomena despite being a little-explored topic, which could allow the development of a more concise guide when considering green technologies within strategic planning.

Keywords: Green information systems, organizational performance, environmental strategies.

Resumen

El cuidado hacia el medioambiente se ha convertido en un tema relevante hacia la industria, ya que la ausencia de este puede causar estragos irreparables. El propósito de este estudio fue desarrollar una escala para evaluar a los sistemas de información verdes, las estrategias ambientales y el rendimiento organizacional en el sector manufacturero. Se recolectaron 99 cuestionarios válidos. La metodología utilizada para el tratamiento estadístico de los datos se llevó a cabo mediante un análisis factorial exploratorio que muestra que los ítems referentes se estructuran similarmente a su antecedente teórico, mientras que un análisis confirmatorio permitió validarlo estadísticamente. Los resultados indican que la escala propuesta demostró ser adecuada para medir los fenómenos descritos a pesar de ser un tema poco explorado, el cual podría permitir desarrollar una guía más concisa al considerar las tecnologías verdes dentro de la planeación estratégica.

Palabras clave: Sistemas de información verdes, rendimiento organizacional, estrategias ambientales.

Introduction

Recently, the environment has been deteriorating alarmingly (Maclean and Wilson, 2011); this has caused sustainability and its different ways of developing it to become a trending topic among the research branches associated with business sustainability (Gholami et al., 2018). Poor environmental practices open to several variations of wastage of natural resources such as materials, energy inefficiency, and excessive pollutant emissions (Watson et al., 2010). This has caused enterprises to rely on IT tools to conduct their business operations by considering alternatives and developing strategies to generate a competitive advantage without compromising the environment (Brundtland, 1987; Molla et al., 2011; Sarkar and Young, 2009).

Thus, the related disciplines of developing information technology (IT)-supported business strategies to comply with environmental regulations and create a competitive advantage have increased considerably (Darnall et al., 2008; Meacham et al., 2013; Melville, 2010; Norheim-Hansen, 2018). Now, while IT is considered the backbone of today's economy as it is indispensable for modern business (Loeser et al., 2017), environmental sustainability has also become one of the most addressed social pressures of the decade, as its applicability can play a crucial role in changing the course of action towards sustainable development without neglecting its economic aspect (Elliot, 2013; MacLean and Wilson, 2011).

From this stems the interest of enterprises to develop strategies, supported by IT, that involve the implementation and development of environmental practices since, in addition to promoting environmentally friendly activities or operational processes, they are considered a fundamental factor for the companies' growth, by generating long-term environmental advantages, together with a significant impact on organizational performance (Danso et al., 2019; Lo and Liao, 2021; Seidel et al., 2017; Yang et al., 2018).

Adopting environmental strategies and green technologies in companies can lead them to develop business operations that meet economic objectives while encouraging the protection of the environment; these technologies have been called green information systems (GIS) (Gholami et al., 2018; Sarkar and Young, 2009; Watson et al., 2010). However, the main uncertainty of adopting these practices and technologies lies in the high investment costs, coupled with the complexity involved in integrating them into business processes (Fadel, 2012; Saade and Nijher, 2016; Shaaban and Awni, 2014). In addition to being associated with a significantly high failure rate (Irvine, 2013), their implementation is considered a highly disruptive task with costly technological, strategic, and economic requirements, which can contrast with the potential benefits they can provide (Talib et al., 2015).

On the other hand, in the case of Mexico, few studies address the synergistic impact of environmental strategies and GIS on organizational performance and the key elements that should be considered for their measurement. Therefore, this study's objective is to develop and validate a scale that allows the evaluation of GIS, environmental strategies, and their impact on organizational performance. For this purpose, the paper is structured as follows: i) literature review on green information systems, environmental strategies, and organizational performance, including the different ways of measuring these elements; ii) generation of the proposed scale, iii) analysis of the data to validate the developed scale and iv) conclusions generated from the results obtained.

1. Literature review

GISs refers to the application of information technologies to develop information systems (IS) with the intent to support enterprises' internal operations, but also to help minimize polluting emissions, waste of raw materials and natural resources to reduce corporate environmental footprint (Fang et al., 2018; Khor et al., 2015; Yang et al., 2018) and thus meet their ecological objectives without overlooking their economic aims (Carberry et al., 2019; Chen et al., 2011; Sarkis et al., 2013). Thus, there are numerous types of ISs related to environmental care issues that satisfy this requirement, such as environmental management systems (Acuña et al., 2017), systems for online collaborative work (Bokolo et al., 2018; Yang et al., 2017), systems for monitoring emissions (Imasiku et al., 2019; Khan and Qianli, 2017; Sarkis et al., 2013), process automation (Chen et al., 2011), transportation route optimization (Yang et al., 2018), systems for energy consumption monitoring (Corbett, 2013; Watson et al. 2010), among others.

Now, to evaluate the quality of GISs and their impact on companies, the scientific academy has adapted the natural resource-based view (NRBV) proposed by Hart (1997) and the strategic capabilities that comprise it: pollution prevention, product stewardship, and internal sustainable development. Pollution prevention proposes that companies change their perspective of controlling or cleaning up their waste towards a new vision of preventing or eliminating their waste before generating it, i.e., the capacity of GISs to minimize the excessive generation of waste during operational processes is evaluated (Anthony, 2019; Gholami et al., 2013).

Likewise, the NRBV also includes the stage that corresponds not only to product manufacturing but also to reducing or eliminating the pollution generated during its entire life cycle (Hart, 1997), from the acquisition of materials to the disposal or recycling of the final product (Anthony, 2019; Jenkin et al., 2011). In other words, the ability of GISs to integrate the supply chain, both horizontally and vertically, in an environmentally friendly manner is also assessed (Chen et al., 2018; Gholami et al., 2013).

And finally, GISs are also appraised for their ability to internally transform the enterprise towards a green mindset (Anthony, 2019), i.e., it tries to increase the degree of utilization of clean technologies in the daily activities within the enterprise (Yang et al., 2017). In this way and based on the literature reviewed, it is proposed that the conceptualization and measurement of the GIS would consider the three fundamental elements presented by Hart (1997) in the NRBV: pollution prevention, product stewardship, and internal sustainable development.

Now, to address the social and governmental pressures regarding environmental deterioration that companies have faced over time and that have increased gradually and steadily (Shao, 2019), companies have tried to develop and align business strategies that consider practices to care for the environment, and thus generate a positive perception of a possible better financial future and more specifically, a substantial number of competitive advantages (Brooks et al., 2018; Hart, 1995).

In this sense, Banerjee (2002) emphasizes that environmental motivations or interests must be transformed into strategies if a greener enterprise is to be built and explains that designs are usually limited in reducing emissions and waste of materials; these types of strategies are referred to as functional and organizational strategies (Loeser et al., 2017). Organizational strategies are characterized by considering future opportunities and challenges and describing the fundamental role of GISs in the achievement of long-term environmental goals. This conception is related to the vision formulated by top management, which represents the company's attitude toward the interest of stakeholders and the environment (Aarstad and Jakobsen, 2020).

Now, functional strategies facilitate the management of resources effectively and efficiently to achieve the proposed environmental objectives; they also allow determining concrete plans and thus increase the efficiency of internal operations resources and business processes and improve the competitiveness of the company; in other words, they are considered as strategies that already have an adequate degree of implementation and are in place to create long-term capabilities related to sustainability and the generation of competitive advantages (Aarstad and Jakobsen; Loeser et al., 2017).

However, organizational and functional strategies have been treated from different operational levels (administrative, operational, and managerial, among others); therefore, for environmental activities to be strategically significant, both must be integrated with information technologies (Chen et al., 2011). Consequently, it is proposed that the two levels mentioned above should be considered for conceptualizing environmental protection strategies: organizational and functional. In addition, it is suggested that environmental strategies that require the support of information systems should be seen as perspectives that support the entire company's operations to improve its organizational and commercial performance (Chen et al., 2018).

Now, regarding organizational performance (ORG), this has been a central object of study of management and business practice and is considered the most critical term for business administration (Andersen et al., 2016) since it is recognized as the natural and tangible accomplishments of a unit (such as businesses) concerning its goals and objectives (Ju et al., 2016). In this way and derived from the literature reviewed, it has been possible to evaluate ORG from different conceptions (market competition, strategies, profitability, risk-taking, market penetration, and better utilization of assets, among others) (George et al., 2019; Park and Shav, 2013).

For the manufacturing industry, ORG has often been measured from the operational perspective (operating performance, OP) and financial perspective (financial performance, FP), i.e., events that fall more under the control of firms (product and service quality, efficiency in terms of manufacturing processes, material utilization, shipping logistics, sales, market penetration, etc.) (Feng et al., 2018; Green et al., 2012a, 2012b; Yang et al., 2018). But, on the other hand, it has also been further considered to expand different approaches to evaluate their performance by adopting environmental concerns, changing their ideology, and going beyond the economic aspect, i.e., adopting more versatile techniques by taking into account the possible effects of their decisions on the environment (environmental performance, EP) (Masa'deh et al., 2017; Li et al., 2016; Schaltegger et al., 2019).

2. Method

This study was of an exploratory nature, as it is a phenomenon that has been scarcely studied at an international level, including measurement scales that have been barely tested. Likewise, it is a quantitative study with a non-experimental and cross-sectional design since a snapshot in time was taken by a survey conducted during the second quarter of 2021. Accordingly, a research questionnaire was developed based on the literature review and a content validity conducted by 3 experts in the field (an environmental management manager, an operations manager, and an information technology professor), which permitted the development of a questionnaire composed of 28 items using a 7-point Likert scale (where 1 represents Strongly Disagree and 7 Strongly Agree), as well as the sociodemographic data of the enterprises with 7 general questions (location, type of enterprise, age, and number of employees) and the information unit (years in the position and charge).

The evaluation of the instrument's content was established through experts in the administrative, technology management, and green technology areas, who mainly indicated that the items had the characteristics of sufficiency (to obtain the measurement of each dimension), coherence (logical relationship with the dimension addressed) and relevance (it is essential or necessary), after the initial review, the instrument was administered to a sample of 40 economic units to validate it from its relevance and effectiveness (reliability and internal consistency), thus ensuring criterion and construct validity (Hernández et al., 2014).

For this study, a non-probabilistic convenience sample was collected and applied to mid-level managers of medium and large companies in the Mexican manufacturing sector because these types of companies are considered one of the highest echelons in terms of pollution generation worldwide (Muscatello et al., 2018), in addition to being the most likely to have the economic solvency and adequate technological infrastructure to implement robust information systems (Supramaniam et al., 2014), the sample collected was composed of 99 validated questionnaires.

Of the sample collected, 52% were medium-sized companies (between 31 and 250 employees), and the other 48% were large companies (251 or more employees), with an average age of 36 years in the market. Similarly, of the type of manufacturing companies surveyed, the food industry stands out with 17%, followed by the automotive industry with 12%, the machinery and equipment manufacturing industry with 12%, the primary metal industry with 12%, and the paper industry with 10%. Regarding the information unit, it was identified that 62% of the people surveyed have some managerial or senior management position and that most (54%) have between 6 to 10 years of experience. In terms of geographic distribution, the companies are mainly located in the states of Nuevo León (38%), Tamaulipas (28%), and Querétaro (15%). For the dimensional validation of the scale, exploratory factor analysis was applied, and subsequently, confirmatory factor analysis was performed to evaluate the construct validity of the questionnaire.

3. Results

Once the information was collected, the process used for the statistical treatment of the data was first to perform an Exploratory Factor Analysis (EFA) and a Confirmatory Factor Analysis (CFA) to obtain the theoretical validity of the inferred constructs (Gil et al., 2000). Then, the EFA served to check the scales' dimensional structure and validate the proposed variables' reliability (Lloret-Segura et al., 2014) using SPSS version 24 software by applying the principal axis factorization extraction method and Promax rotation as this produces more accurate and reproducible results by having items that are correlated.

For the AFE, first, the normality of the items used was analyzed, verifying that they retained a skewness and kurtosis within the threshold of ± 1.6, resulting in not all things being found within the proposed interval, indicating that the observations for these indicators did not fall into a normal distribution, but were strongly loaded toward one end of the scale, which could incur problems for subsequent analyses of the AFE. As for the Kaiser-Meyer-Olkin measure of sampling adequacy (0.865) as well as Barlett's test of sphericity ($p < 0.001$), they indicate that the sample is adequate to perform the AFE. The variables extracted show that seven components contribute 73% of the total variance (Table 1).

Regarding the structure of the proposed variables, for the case of green information systems, the construct was separated into three components: pollution prevention (2 items), product stewardship (4 items), and internal sustainable development (2 items); on the other hand, environmental strategies are made up of 7 items, and, finally, organizational performance was separated into three components: operational performance (4 items), financial performance (4 items) and environmental performance (4 items), which can be seen in Table 2. It can also be seen that the factor loadings exceed the established minimum of 0.5; it is worth mentioning that the indicators that did not reach this value were eliminated (PP1, PP2, PP3, SD2, SD4, SD5, EVOR3, EVOR5).

Table 1.

Explained variance of the extracted factors.

Factor	Sum of the squared saturations of extraction			Sum of the saturations squared by rotation
	Total	% Of variance	% Accumulated	Total
1	13.227	48.988	48.988	9.849
2	2.286	8.465	57.453	9.419
3	1.403	5.198	62.651	8.980
4	1.090	4.036	66.687	7.695
5	.731	2.706	69.394	8.918
6	.536	1.984	71.378	7.683
7	.450	1.665	73.043	5.257

Note: Own elaboration.

Table 2.

Configuration matrix of the extracted factors.

Dimension	Item	Indicator	Load
Pollution prevention	PP4	The information systems used in the company allow monitoring/control of pollutant emissions produced.	.594
	PP5	The information systems used in the company allow monitoring/controlling of the use of toxic and hazardous materials.	.654
Product stewardship	PS1	The information systems used by the company facilitate greener procurement of materials.	.624
	PS3	The information systems used by the company support the manufacture of environmentally friendly products.	.883
	PS4	The information systems used by the company facilitate the manufacture of products using leftover or recycled materials.	.717
	PS5	The information systems used by the company save fuel by optimizing product delivery routes.	.566
Sustainable	SD1	The company uses information systems to facilitate	.789

development		compliance with environmental standards (e.g., ISO 14001).	
	SD3	The company uses information systems to eliminate and deactivate unused services and systems.	.662
Organizational strategies	EVORG1	Top management recognizes the organizational and profit potential of environmental stewardship strategies.	.688
	EVORG2	Top management emphasizes the role of green strategies in driving environmental development in the company.	.885
	EVORG4	Top management considers information systems to be an essential tool for fulfilling green strategies.	.854
Environmental strategies	EVFUN1	During IT implementation processes, environmental protection aspects have been integrated.	.582
	EVFUN2	During IT implementation processes, high preference is always given to promising technological projects from an ecological perspective.	.721
	EVFUN3	During IT implementation processes, performance indicators have been established to evaluate the impact of environmental initiatives from a technological point of view.	.760
	EVFUN4	While formulating environmental strategies, financial and other resources have been allocated to environmental initiatives.	.796
Operative performance	OP1	With the use of information systems, the company has managed to increase its customer satisfaction levels.	.702
	OP2	With the use of information systems, the company has been able to reduce its product delivery times.	.701
	OP3	With the use of information systems, the company has been able to reduce operational risks.	.961
	OP4	With the use of information systems, the company has been able to increase its degree of reuse of materials to manufacture products.	.853

Environmental performance	EP1	With the use of information systems, the company has been able to reduce the use of toxic or hazardous materials to manufacture products.	.675
	EP2	The company has been able to reduce polluting emissions using information systems.	.856
	EP3	The company has been able to reduce the use of natural resources (e.g., water, gas, coal, etc.) using information systems.	.813
	EP4	With the use of information systems, the company has managed to increase its customer satisfaction levels.	.869
Financial performance	FP1	The company, using information systems, has improved its average return on sales in generates.	.630
	FP2	The company, using information systems, has increased its average return on investment.	.854
	FP3	The company, using information systems, has increased its average profits.	.881
	FP4	The company, using information systems, has increased its material waste savings.	.584
		Eliminated indicators	
Pollution prevention	PP1	The information systems used by the company provide information on the environmental impact of all manufacturing processes within the plant.	
	PP2	The information systems support compliance with the company's environmental, health and safety regulations.	
	PP3	The information systems used by the company allow for monitoring/controlling material consumption.	
Sustainable development	SD2	The company uses information systems to facilitate collaborative work in digital media among employees.	
	SD4	The company uses information systems to facilitate	

		operations in all departments of the company (e.g. just-in-time systems for distribution and inventory control or systems for customer administration).
	SD5	The company uses centralized information systems to eliminate the use of paper in its operational and communication processes as much as possible.
Organizational strategies	EVOR3	Senior management demonstrates a high level of involvement in relation to green initiatives.
	EVOR5	Senior management responds in a timely manner to early signals of areas of opportunity with respect to environmental stewardship (e.g. green products, reverse logistics, use of renewable energy, environmental planning, etc.).

Note: Own elaboration

As for the internal consistency of the obtained scores, this was evaluated through the communalities and convergent validity of the indicators, the Cronbach's Alpha coefficient (α), and the discriminant validity of the extracted factors. Beginning with the discriminant validity, Table 3 shows that the extracted factors have an adequate discriminant validity with a correlation of less than .700 between them. Subsequently, Table 4 shows that all the indicators have an extracted value in their communalities higher than .400, so they are considered acceptable. On the other hand, most variables showed a value above .700 in Cronbach's Alpha, i.e., all the factors extracted have an adequate internal consistency.

Table 3.

Matrix of correlations between factors.

Matrix of correlations between factors							
Factor	a	b	c	d	e	f	g
Environmental strategies (a)	1.000						
Product stewardship (b)	.616	1.000					
Operational performance (c)	.555	.558	1.000				
Financial performance (d)	.411	.545	.661	1.000			
Environmental performance (e)	.582	.600	.606	.579	1.000		
Sustainable development (f)	.587	.623	.496	.448	.525	1.000	
Pollution prevention (g)	.452	.507	.356	.286	.396	.561	1.000

Note: Own elaboration.

Table 4.

Communalities and internal reliability.

Variable	Item	Initial	Extraction	α
Pollution prevention	PP4	.719	.847	.917
	PP5	.719	.847	
Product stewardship	PS1	.614	.711	.873
	PS3	.547	.675	
	PS4	.525	.595	
	PS5	.515	.571	
Sustainable development	SD1	.465	.681	.802
	SD3	.465	.681	
Environmental strategies	EVORG1	.709	.638	.947
	EVORG2	.780	.752	
	EVORG4	.593	.584	
	EVFUN1	.717	.700	

	EVFUN2	.694	.710	
	EVFUN3	.794	.813	
	EVFUN4	.659	.671	
Financial performance	FP1	.798	.692	.904
	FP2	.805	.730	
	FP3	.851	.750	
	FP4	.783	.662	
Environmental performance	EP1	.801	.689	.896
	EP2	.832	.739	
	EP3	.792	.729	
	EP4	.779	.687	
Operative performance	OP1	.621	.708	.896
	OP2	.479	.534	
	OP3	.679	.782	
	OP4	.647	.733	

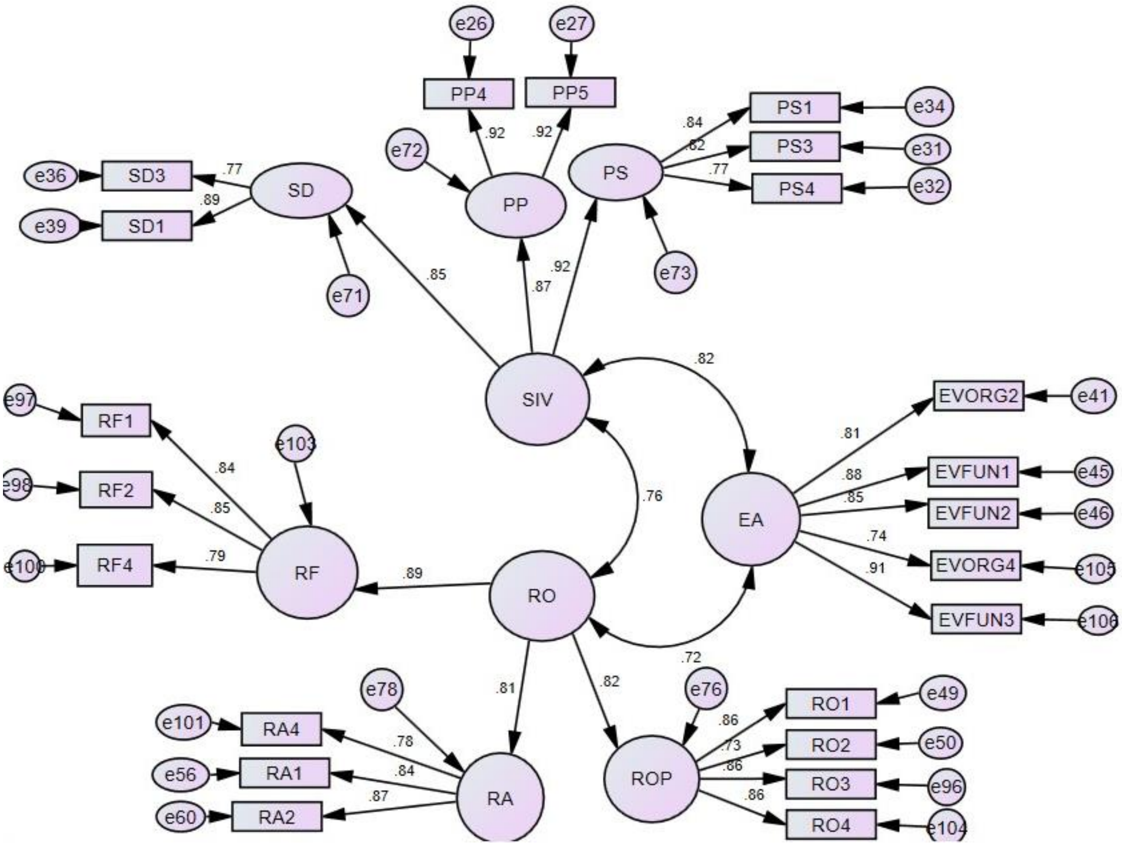
Note. Own elaboration.

Having obtained the information from the EFA to define the dimensional structure of the proposed constructs, the CFA was performed to demonstrate the theoretical validity of these deductions, i.e., the solutions obtained utilizing the EFA were validated (Gil et al., 2000). For this, in addition to validating the construction of the applied questionnaire, the CFA was performed by employing Structural Equation Modeling (SEM) analysis with the AMOS statistical package version 24 (Arbuckle and Wothke, 1999), applying a structural covariance analysis to a sample of 2 to 4 indicators selected for each construct, to identify the model that significantly reproduces the scores used to measure the GIS, the environmental strategies and the ORG.

The results obtained from the CFA indicate that the scales proposed to measure GIS, environmental strategies (scale not very tested), and ORG are valid, as they satisfactorily represent the constructs established by the literature reviewed (see Figure 1). To verify that the results were statistically accurate, the invariance of the model was tested, starting with the internal consistency of the indicators, the convergent and discriminant validity, and finally, the goodness-of-fit index.

Figure 1.

The model results from the confirmatory factor analysis.



Note. Own elaboration.

For construct validity, first, the composite reliability (CR) was analyzed, verifying that each construct had a minimum value of .700 (Hu and Bentler, 1999) and that each construct had an appropriate Average Variance Explained (AVE), with a minimum value of .500. Likewise, it was also relevant to analyze the discriminant validity of the model through the Heterotrait-Monotrait Ratio of Correlations (HTMT) matrix to ensure that the constructs are only the phenomenon for which they were proposed (Henseler et al., 2015). As can be seen in Table 5, the constructs meet the criteria mentioned earlier, in addition to having an appropriate discriminant validity, since the HTMT matrix indices have values below .850 (Henseler et al., 2015; Hu and Bentler, 1999).

Table 5.

Composite reliability, convergent and discriminant validity (HTMT criterion) of the constructs.

	CR	AVE	GIS	RO	EA
GIS	.91	.733	-		
RO	.88	.712	.697	-	
EA	.92	.870	.801	.681	-

Note. Own elaboration.

Finally, to evaluate the model's goodness-of-fit index, the model was assessed using two absolute indices (relative chi-square [x^2/gl]) and the standardized root mean square residual (SRMR) and two relative indices (comparative fit index, CFI) and the root mean square error of approximation (RMSEA) (Hu and Bentler, 1999). As seen in the criteria included in Table 6, all the indices have satisfactory values, indicating that the model has an appropriate level of fit and that it is not measuring more information than it intends to estimate.

Table 6.

Model fit.

Measurement	Result	Acceptance threshold	Interpretation
x^2	279.279	-	-
gl	200	-	-
x^2/gl	1.399	Between 1 and 3	Excellent
CFI	0.952	> .95	Excellent
SRMR	0.056	< .08	Excellent
RMSEA	0.064	< .06	Acceptable
PClose	0.107	> .05	Excellent

Note: Own elaboration.

4. Conclusions

The objective of this study was to construct a scale applicable to green information systems, environmental strategies, and organizational performance. However, after studying the metric properties of the scale, significant problems of internal consistency were found, mainly of the GISs, starting with the uniform distribution along the seven items of the scale, causing high abnormality indices, its lack of homogeneity with the rest of the items can be attributed to the loss of clarity during the translation into Spanish, causing that the people who answered the questionnaire did not fully understand the items in question.

Nevertheless, the proposed scale proved to be adequate to evaluate the phenomena described by analyzing information systems from an environmental context, environmental strategies, and organizational performance. Although the internal consistency and goodness of fit of the model improved significantly with the elimination of a considerable number of indicators, this is considered normal in the study of poorly tested scales such as the one used for environmental strategies and GISs, particularly in Mexico, since to date a wide range of studies analyzing these technologies and their particularities that can contribute to tangible benefits in companies in the manufacturing sector has not been consolidated.

The main contribution of this study is the discussion within the literature on information technology management and environmental management and, consequently, to contribute to the identification of those guidelines that can have a more significant influence on environmental protection and the development of companies, through the conceptualization and scope of a concept that has been little addressed in Mexico, In this way, it is possible to build a scale of measurement to centralize these tools, to develop a more concise guide to be considered during the strategic planning of the integration of IS projects by the companies and to ensure that the expected benefits are reflected intangible results.

As a limitation of the study, it should be noted that the sample is considered somewhat small, as the collection was conducted during a single period and at a time that was affected by the SARS-Cov-2 virus pandemic (COVID-19). Nevertheless, a sample of 99 observations can be considered sufficient to reach acceptable levels of statistical power (Chin and Newsteed, 1999; Cohen, 1998; Faul et al., 2009; Green, 1991; Reinartz et al., 2009). Likewise, it is pertinent to clarify that in order to ensure the replicability of the instrument, it is recommended that future researchers collect a more robust sample. On the other hand, it should be mentioned that GIS were only considered from an administrative-managerial context, so future researchers are invited to consider more elements that ensure the achievement of various organizational benefits (such as compatibility with tasks or processes, quality of service, information and software, cost minimization, user perceptions, among others).

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