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Research article

A Continuous Improvement Instrument for the evaluationof the ergonomics management system in the supply chain

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ABSTRACT

Nowadays, organizations must comply with high-quality standards, health and safety regulations, and socially sustainable practices to succeed in a globalized world. Supply Chains (SC) enable them to satisfy their customers' needs for quality products just in time and at the best price. However, management systems (MS) need to be improved to identify, evaluate, and control ergonomic risks, which opens a research opportunity for Ergonomics Management Systems (EMS) as they apply to sustainable SCs. This study aims to design and validate an instrument to assess the EMS within a SC using a continuous improvement approach. The study used convenience sampling as experts were invited by e-mail, at congresses, and through a digital platform. A response rate of 6.2 % was obtained from the latter, and a total of 34 experts responded to the instrument. An exploratory factor analysis (EFA) and a confirmatory factor analysis (CFA) were also carried out for the constructs of PLAN, DO, CHECK, and ACT. Finally, factors and variables were reduced by 42.71 %, leaving a 46-item final version of the instrument. Most of the structural model fit indices for the sample demonstrated good values, and the reliability indices were acceptable, this confirming the overall reliability of the instrument. In conclusion, the instrument was validated for all proposed constructs, with the exception of the PLAN construct. Thus, the instrument was found to be relevant and fit for implementation in EMS.

1. Introduction

Today, organizations must comply with considerably high-quality standards [1], a stringent environment [2,3], and health and safety regulations [4,5] to succeed in a globalized world. In addition, they must effectively and efficiently meet the need for products of

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the highest quality and at the best price and deliver them to customers around the world just in time. All of the above involves complex supply chains made up of companies competing for a place in the market [6,7]. A supply chain (SC) has been traditionally defined as a unidirectional integrated manufacturing process in which raw materials are converted into final products and then delivered to customers; only manufacturing activities are included, from the acquisition of raw materials to the delivery of goods [8]. On the other hand, Coyle et al. [9] conceive it as a series of connected companies that must share information and coordinate physical execution to guarantee a smooth, streamlined flow of goods, services, information, and money. These enterprises are known as links, and the improvement of their performance results in the improvement of the entire SC.

In the literature, SCs have been the subject of study and evaluation by several aspects such as quality [10], flexibility [11], leanness [12,13], and sustainability [14] among others. However, Sampouw & Hartono [15], Perttula [16], and Cantor [17] have pointed out the need for comprehensive studies to evaluate Ergonomics practices and Ergonomics Management System (EMS) throughout the SC under a holistic vision that takes these aspects into consideration. Actual management systems (MS) need to be improved to identify, evaluate, and control ergonomic risks, which opens a research opportunity for Ergonomics Management Systems (EMS) as they apply to sustainable SCs.

Currently, management systems (MS) play a crucial role in organization development by providing a structured and systematic means to achieve objectives, thus improving work performance [18]. Additionally, more and more organizations have recently started to implement management systems in various fields such as quality (QMS) [1,19], environment [20,21], and health and safety (HSMS) [22–24] among others. All these approaches have been unified and have evolved into integrated management systems (IMS) that include ergonomic aspects [25–28]. However, these same authors found that the IMS and HSMS have been deemed insufficient for the identification, evaluation, and control of ergonomic risks since both systems are geared primarily to accident prevention-oriented programs. Further opportunities of improvement for these systems are their limited scope of assessments and solutions, since these respond to specific aspects and needs of the organizations, and their need to define ergonomics management dominions and constructs. This scenario has opened a research opportunity to propose a tool for adequate Ergonomics Management System (EMS) evaluation [29]. Additionally, the term ergonomics management is still a "work in progress" as it lacks a clear and accepted definition in the literature. However, modern approaches to quality management and health and safety have clarified some of its domains and characteristics through various models and standards [29].

Likewise, the continuous improvement philosophy has been recognized as one of the most widely accepted and effective strategies to evaluate EMS in the SC [29]. Continuous improvement entails the implementation of the Plan-Do-Check-Act (PDCA) cycle, which is a systematic process designed to obtain valuable learning and knowledge for the continuous improvement of a product, process, service, or system. This management model is based on four processes, which are defined by ISO 45001 [30]: 1) Plan, which involves establishing the objectives of the system and its processes as well as the resources needed to deliver results according to customer requirements and organization policies, and which also involves identifying and addressing risks and opportunities; 2) Do, which means the implementation of what was planned; 3) Check, which consists of monitoring and (where applicable) measuring processes and the resulting products and services against policies, objectives, requirements, and planned activities, and which also includes the reporting of the results; and 4) Act, which means to take the necessary actions to improve performance. This four-process model can provide the supply chain with greater control, enabling it to continuously improve processes, products, or services and thus achieve greater customer satisfaction [31]. In addition, its high degree of flexibility allows it to be used in various processes or organizational functions. Finally, it is considered a simple but effective model as its processes are easy to understand, and the tools needed for its implementation are easy to use. However, the results and solutions derived from the PDCA cycle can have a significant impact on the members of the SC.

In the search for continuous improvement, Sampouw & Hartono [15], Perttula [16], and Cantor [17] noted the need to carry out comprehensive ergonomics studies throughout the SC and evaluate all the links with a holistic vision. In addition, these authors addressed the need for the supply chain to implement strategies and practices that contribute to sustainability, increase profitability, and reduce or eliminate negative environmental and social effects. It is in this last aspect that EMS's greatest contribution can be found as it focuses on the workers' wellbeing by complying with ergonomics practices.

As can also be confirmed in the literature, ergonomics management and application have had both economic benefits and a positive impact on workers' well-being and quality of life in companies that have implemented them successfully [32–35]. That is why, these authors propose the need to develop an EMS model to evaluate the whole SC as well as each of its links.

The objective of this research work is, thus, to rely on experts in ergonomics, health and safety, management systems, and logistics and to use both an Exploratory (EFA) and a Confirmatory Factor Analysis (CFA) to validate a new instrument that can be part of the model to evaluate the EMS in the SC. The contribution of this article lies on the development of a new, valid, and reliable instrument for the evaluation of Ergonomics Management System in the SC, based on compliance with good practices and requirements resulting and adapted from the ISO 45001 standard and on the continuous improvement approach, applicable throughout the SC. In addition, it will contribute to the coining of the Ergonomics Management System concept and will establish theoretical bases for the socially sustainable design of the SC from an ergonomic approach. The research hypothesis is.

H1. The proposed Continuous Improvement Instrument for Ergonomics Management System Evaluation is statistically valid for assessment of the supply chain through the constructs (Plan, Do, Check, and Act).

1.1. The concept of ergonomics management system (EMS)

Considering that ergonomics management is a concept that is still being developed, the literature analyzed in this section clarifies

the term and explains it from the words and constructs: *management system* and *ergonomics*. The first term, Ergonomics or Human Factors, is defined by the International Ergonomics Association as the body of scientific knowledge that is applied to ensure that work, systems, products, and environments are adapted to meet individuals' physical and mental capabilities and limitations. It is also the scientific discipline concerned with understanding the interactions between humans and other elements of a system. Finally, it can be described as the profession that applies theory, principles, data, and methods to designs that can optimize human well-being and overall system performance [36]. On the other hand, management refers to the set of actions or endeavors that enable any activity or desire, the solution of a situation, or the materialization of a project [37]. It is also related to the set of procedures and actions that are carried out to achieve a certain objective [38]. From the business perspective, it is easy to relate it to a management system since the International Organization for Standardization (ISO) defines it as that set of elements of an organization that interrelate or interact to establish policies, objectives, and processes to meet the established goals. Among the elements to be considered are the organization's structure, roles and responsibilities, and planning, operation, performance evaluation, and continuous improvement processes.

In light of the two afore mentioned concepts, this research has defined EMS as the set of procedures and actions that serve to create a plan, identify risk factors, execute a program, establish control through good practices, and set objectives to reduce or eliminate ergonomic risks and hazards from the man-machine system and environment. The definition involves the consideration of people's physical and mental capabilities and limitations, as well as the presence of change dynamics, staff participation, and continuous improvement, to optimize human welfare and the overall performance of a system.

1.2. The ISO 45001 provides an opportunity for ergonomics management system in the supply chain

Since its initial stage, ISO 45001 sought to ensure a "robust and effective set of processes to improve occupational safety in global supply chains" [39]; in other words, it pursued a sustainable solution to promote occupational health and safety in global supply chains. This standard is based on the PDCA cycle model, the iterative-process that organizations typically use to achieve continuous improvement. Therefore, it can be explored as a value-added capability for global supply chains. Regarding safety management systems, the proposed structure in ISO 45001 provides a common framework and terminology for managing hazards in the workplace. This same framework can be applied to systematically identify, control, and verify the reduction of related risk factors.

Furthermore, Rostykus et al. [40] state that the use of a management system to align the way in which the organization addresses ergonomics allows Occupational Safety and Health professionals to communicate with and engage business leaders in a way that is already familiar to them. In addition, these authors confirm that the ISO 45001 model can be used as an effective system for ergonomics management as it identifies and communicates hazards and addresses their analysis and mitigation. It also offers system improvement opportunities; for example, the need to assess ergonomics and injury prevention [30]. Using these findings as a starting point, this research developed an ergonomics management evaluation instrument based on ISO 45001 and the PDCA cycle as an elementary structure due to its relevance and pertinence [29]. Table 1 shows the four domains to be considered in the instrument, numbered from 6 to 10. These domains are based on an extensive literature review [29] and are classified for each construct.

2. Method

The research was statistical, empirical, and cross-sectional. The Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) play the leading role in the statistical validation of the new instrument for the evaluation of the Supply Chain Ergonomics Management (SCEM) and were conducted by experts in ergonomics, health and safety, management systems, and logistics. The designed instrument contains questions related to the participants' level of agreement regarding compliance with SCEM practices and requirements.

Table 1
EMS constructs and domain.

PDCA Cycle	ISO 45001:2018 Occupational health and safety management systems - Requirements with guidance for use	
	Constructs	Domains
Plan	6 **Planning**	6.1 Actions to address risks and opportunities
		6.2 Objectives and planning to achieve them
Do	7 **Support**	7.1 Resources
		7.2 Competence
		7.3 Awareness
		7.4 Communication
		7.5 Documented information
	8 **Operation**	8.1 Operational planning and control
		8.2 Emergency preparedness and response
Check	9 **Performance evaluation**	9.1 Monitoring, measurement, analysis, and evaluation
		9.2 Internal Audit
		9.3 Management review
Act	10 **Improvement**	10.1 General
		10.2 Incident, nonconformity, and corrective action
		10.3 Continuous improvement

Source: Rodríguez-Gámez et al. [29].

2.1. Participants

The participants in this study were experts with at least five years of experience in one of the following areas of knowledge: ergonomics, health and safety, management systems, and supply chain (logistics). They were also required to be university professors, consultants, supervisors, managers, or directors in either public or private organizations across Latin America. Data collection began in May 2022 and ended in November 2022 and was carried out through a structured instrument that was converted into an electronic survey using the jotform.com® platform. These experts agreed to participate voluntarily and signed a consent form under the CEI-2022-1-591 evaluation and resolution, granted by the *Universidad Autónoma de Ciudad Juárez* (Autonomous University of Ciudad

Table 2
Sample characteristics ($n = 34$).

Characteristic	Frequency	%
Country		
Mexico	22	64.71
Chile	3	8.82
Ecuador	3	8.82
Venezuela	3	8.82
Colombia	1	2.94
Cuba	1	2.94
Peru	1	2.94
Gender		
Male	26	76.47
Female	8	23.53
Academic level		
PhD	12	35.29
Master's degree	15	44.12
Bachelor's degree	5	14.71
Ergonomics Specialist	2	5.88
Academic Background		
Health Sciences	11	32.35
Engineering, manufacturing, and construction	20	58.82
Business and Management	2	5.88
Social Sciences and Law	1	2.94
Sector		
Public Sector (Academic)	19	55.88
Private Sector (Mining, Manufacturing, or Consulting)	20	58.82
Both sectors	9	26.47
Ergonomics experience (years)		
>25	5	14.71
21–25	4	11.76
16–20	6	17.65
11–15	4	11.76
6–10	4	11.76
2–5	10	29.41
1	1	2.94
Occupational Health and Safety experience (years)		
>25	9	26.47
21–25	4	11.76
16–20	4	11.76
11–15	3	8.82
6–10	7	20.59
2–5	6	17.65
1	1	2.94
Management systems experience (years)		
>25	5	14.71
21–25	3	8.82
16–20	2	5.88
11–15	7	20.59
6–10	6	17.65
2–5	10	29.41
0	1	2.94
Logistics experience (years)		
>25	2	5.88
21–25	1	2.94
16–20	2	5.88
11–15	1	2.94
6–10	4	11.76
2–5	11	32.35
1	10	29.41
0	3	8.82

Juarez, UACJ) Research Ethics Committee. Convenience sampling was used [41], primarily due to the difficulty in accessing experts from different institutions in Latin America, who met the needed criteria and had the availability to participate in the research. Finally, resources such as time, money, and people were limited.

Consequently, the three following strategies were used to invite experts to participate.

1 Through emails to contacts in the research network
2. By broadcasting the project in international forums and congresses
3 By issuing invitations through the LinkedIn.com platform

The sample was conformed by ten experts who participated in response to the email invitations, and six who responded to the second strategy. Regarding the third type of invitation, LinkedIn.com® used job profiles to help locate experts in safety, ergonomics, management systems, and logistics. A total of 286 experts from different countries were identified and verified; then after receiving an invitation, a total of 6.2 % (18) individuals participated. In sum, the total number of participants resulting from the three strategies, was n = 34 expert responses.

The above-mentioned strategies made it possible to collect information from experts across Latin America. Table 2 shows the characteristics of the participants.

2.2. *The Continuous Improvement Instrument for Ergonomics Management System Evaluation (CIEMSE)*

The Continous Improvement Instrument for Ergonomics Management System Evaluation (CIEMSE) is based on four constructs taken from the continuous improvement philosophy (Plan, Do, Check, Act). Before designing it, this study conducted a systematic literature review of the models, management system, and the ISO 45001 standard requirements and practices [29]. The resulting 87 close questions were defined and reviewed by six experts who suggested either their redefinition or their elimination. The items were answered through a 5-point Likert-type rating scale, where responses assessed compliance with EMS's practices and requirements in the SC through a scale from 1 = Strongly disagree to 5 = Strongly agree. The instrument's final version contained two sections: 1) the participants' sociodemographic data and 2) the continuous improvement approach (Plan, Do, Check, and Act). Lastly, the instrument was provided with an introductory section as well as instructions for its completion.

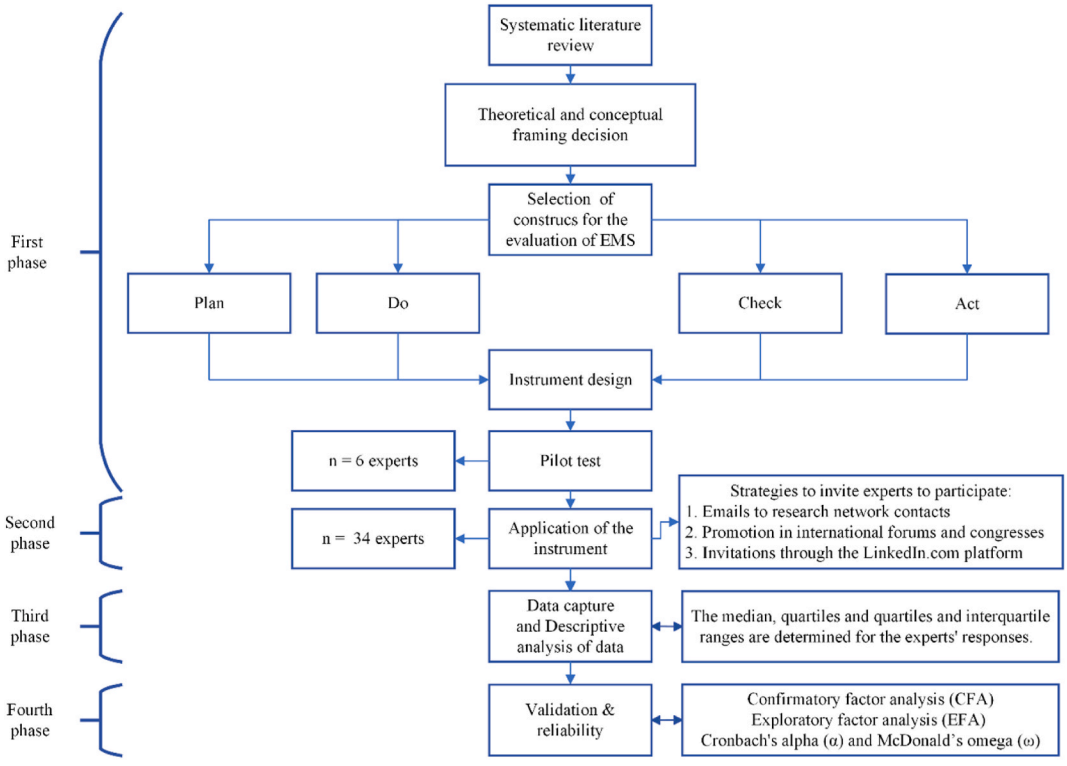

Fig. 1. Phases involved in the research process.

2.3. Methodology

The methodology included designing, applying, and validating an instrument for EMS evaluation. It also consisted of 6 phases, shown in Fig. 1 and described in the following sections.

2.3.1. First phase: instrument development

A set of robust state-of-the-art Management Systems, Standards, and Models was established during this phase. In addition, a systematic literature review was conducted in accordance with the PRISMA Declaration [42] to analyze the theoretical and conceptual framework of reference for EMS in SC and identify the constructs and dimensions that would make up the evaluation instrument, which can be consulted for further reading [29]. Fig. 2 shows the five stages in the process design.

Once a theoretical and conceptual decision was made regarding the design of the instrument's elements, the aspects proposed by Tsang et al. [43] and Taherdoost [44] were considered to establish the constructs to be measured. Next, the instrument's content, scope, and target population were defined. These aspects determined the content and structure of the fieldwork needed for the data collection for each item. Then, the list of items to be assessed for each construct was created. Closed questions, the measurement scale for each item, and the coding of polychotomous responses were also agreed upon. Once such questions were arranged throughout the instrument, its integral design was completed. At the end, the instrument was revised for content and language, and refined by means of a pilot test as well as the judgment of six experts. The initial items were either redefined or deleted, giving way to the preliminary version. The instrument's special features are described in detail in Part 3.2 of the Materials and Method section.

2.3.2. Second phase: instrument administration

During this phase, the administration of the data-collection instrument was planned and conducted. Details of the CIEMSE administration (fieldwork) are provided in the Method section under Part 2.1, "Participants."

2.3.3. Third phase: data entering and descriptive analysis

Experts' responses were entered into a database using the SPSS 23® software. Then the data underwent a cleaning and screening process so that possible input errors, outliers, missing data, and unexpected variability could be identified. Such outliers and missing values were replaced using the median substitution method since the data was entered initially on an ordinal scale [45,46].

Next, a descriptive analysis of the experts' responses was conducted for each element or section of the instrument. Central tendency measures (the median values) and dispersion measurements (quartiles and interquartile ranges) were used for this purpose, as suggested by Ref. [33]. The highest median values represent the degree of acknowledgement of the most accepted EMS evaluation practices and requirements. In contrast, the lowest values represent the lowest degree of consensus. The interquartile range value represents the degree of response dispersion: the higher the value, the greater the dispersion [47].

2.3.4. Fourth phase: validation & reliability

2.3.4.1. Exploratory factor analysis (EFA). A content and construct validity analysis was conducted to examine the instrument's validity. Six experts were asked to determine content validity based on their experience and knowledge of the literature on management systems, ergonomics, supply chain, safety and occupational health. They all agreed on the items' relevance, congruence, and clarity but also suggested that content changes be made to enable a more complete and adequate measurement of the CIEMSE constructs. Construct validity was achieved by developing an EFA and a CFA to reduce dimensions. An EFA was developed for each construct using the SPSS 23® software, considering the unweighted least squares extraction method. Furthermore, to obtain a better interpretation of the factors, a rotation was conducted through the Varimax method [48]. Relevance was assessed at the initial stage of this analysis by using the KMO (Kaiser-Mayer-Olkin) index and Bartlett's test of sphericity. The KMO index was considered adequate as it featured a level of 0.60 [49]; in Bartlett's test, the significance was lower than 0.05. In addition, the rotated component matrix was analyzed to determine whether a given item in the construct would remain as a function of the factor loadings. Since values greater than or equal to 0.5 are considered strong [50], the communalities of each item were also examined to analyze their contribution; the correlation matrix was established [52] and a value of 0.5 was set as a cut-off point [51].

2.3.4.2. Confirmatory factor analysis (CFA). Once the EFA yielded adequate indices, a CFA was conducted, using the AMOS 24® software, to verify the CIEMSE items' reliability and validity and to optimize their construction [53]. The procedure involved three steps. The first one consisted of estimating each construct's measurement models (first order) and examining their standardized coefficients (factor loadings λ) to determine the variance of each of the indicators that explained the construct. The second step was to eliminate from the models the items that failed to meet the criteria proposed by Jöreskog & Sörbom [54]: 1) have statistically significant parameters at the 95 % level (t-student greater than 2.58); 2) feature factor loadings greater than 0.50; and 3) show an $R^2 >$

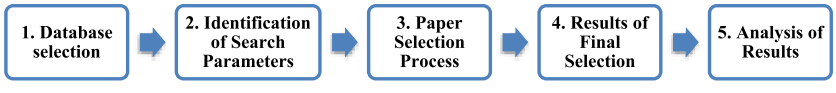

Fig. 2. Stages in the literature review process.

0.30. The third step was to use different indices to determine the degree of model fit for each construct. Two perspectives were considered: absolute fit and incremental fit. Four parameters were used for absolute fit and three for incremental fit, which is shown in Table 3.

2.3.4.3. Internal consistency (Cronbach's alpha and McDonald's omega). For data analysis and evaluation of internal consistency, the CIEMSE was subjected to a reliability analysis using Cronbach's alpha (α) statistic [58] and McDonald's omega coefficient (ω) [59]. Although the former is more widely used for this purpose, the McDonald's omega coefficient provides a more stable value since it is obtained from weighting factors, i.e., the weighted sum of standardized variables. Both statistics consider that a value of ≥ 0.70 shows adequate reliability; however, a minimum value of at least 0.90 is recommended given that the goal is to produce a concise scale [60, 61].

3. Results

This section will describe the CIEMSE's validation (EFA and CFA for each construct: Plan, Do Check, and Act) and reliability results.

3.1. Exploratory factor analysis (EFA) by sections

The EFA showed KMO indices above 0.728 for each construct, in accordance with the instrument's initial design. However, the "Do" construct obtained an index of 0.369; therefore, it is not deemed convenient as an exploratory factor analysis tool. After analyzing the correlations among the "Do" construct's variables, the items with the least contribution to its explanation were eliminated, which led to the reaching of an acceptable index. As for the Bartlett's test of sphericity, its results were significant for all constructs, featuring p-values <0.001, as shown in Table 4. This indicates that the relationship between the variables was strong, and the data were suitable for EFA performance [62]. Leech et al. [63] also hold that the items are sufficiently corrected when the associated probability is < 0.05. Finally, Table 4 contains the results of the CIEMSE final version (See Appendix A); they show KMO values of more than 0.7 for the four constructs (Plan, Do, Check, and Act), which is proof of adequate validity. As for the significance of Bartlett's test of sphericity, p values < 0.001 were obtained, which confirms that the correlations of the items in each construct are relatively compact and guarantee reliable results in the factor analysis. The same test confirms that the items are sufficiently associated with each construct of the CIEMSE.

In the search for item communality, four items were identified and eliminated from the instrument, two of them belonging to the Plan construct (PL@1 = 0.351 and PL@17 = 0.418), one to the Do (DO@22 = 0.475), and one to the Check (CH@22 = 0.377). In turn, the rotated component matrix of each construct yielded weighting factors greater than 0.4. Additionally, although six items (PL@5, PL@8, PL@9, DO@14, and CH@10) featured similar values in two or more factors, they were eliminated after their content and relevance to construct explanation were reviewed. Appendix B shows the results of the CIEMSE's final version by showing the rotated components matrix and the Act construct's components matrix since it only presented one factor, whereas the EFA proposed two and three factors for the rest of the constructs.

3.2. Confirmatory factor analysis (CFA) by section

As a starting point, the EFA provided the first-order model structure for each construct and represented them in the initial structural models. Table 5 shows the initial model fit results for the five constructs that make up the CIEMSE.

These initial models' results are considered appropriate starting points as they lie outside the acceptable adjustment parameters of the different measurement models for each construct. The final version of the CIEMSE was obtained after the factorial loading, R^2, and statistical significance $(p-valor \leq .01)$ values and the covariance relationship of the items' errors for each construct were analyzed. A variable reduction process was also conducted, which resulted in the deletion of thirty-two items from all constructs.

Figs. 3–6 show the last version of each construct's measurement models, featuring the standardized estimates. The factor loadings of the items that make up the Plan construct range between 0.69 and 0.96, while the R^2 values are greater than 0.46.

Table 3
Goodness-of-fit measures and cut-off parameters.

Goodness of fit measure	Levels of acceptable fit	Bibliographic Reference
Absolute adjustment		
1. Chi-square (χ^2) or Minimum discrepancy index (CMIN).	p > 0.05 CMIN/Df = 2 - 3	[55]
2. Goodness-of-fit index (GFI)	GFI ≥0.90	[55]
3. Root mean squared error (RMSEA)	RMSEA <0.05–0.08	[56]
4. Standardized root mean squared residual (SRMR)	SRMR ≤0.08	[57]
Incremental adjustment		
1. Comparative fit index (CFI)	CFI ≥0.90	[56]
2. Tucker-Lewis's index	TLI ≥0.90	[55]
3. Bentler-Bonett Index (NFI)	NFI ≥0.90	[56]

Table 4
Kaiser Meyer Olkin's (KMO) and Bartlett's test results.

Construct	Initial instrument (87 items)						Final CIEMSE (46 items)					
	KMO	Bartlett's test of sphericity					KMO	Bartlett's test of sphericity				
		Chi-Square	Df	Sig.	No. factors	% Explained Variance		Chi-Square	Df	Sig.	No. factors	% Explained Variance
Plan	0.779	854.510	231	0.000	3	76.87	0.805	273.707	45	0.000	2	77.01
Do	**0.369**	1668.363	435	0.000	4	82.25	0.860	474.514	66	0.000	2	83.03
Check	0.728	1094.872	253	0.000	4	86.66	0.860	558.432	91	0.000	3	87.32
Act	0.866	527.659	66	0.000	2	86.09	0.879	423.978	45	0.000	1	81.99

Table 5
Initial model fit results.

Construct	Initial Model								
	Chi-Square	Df	CMIN/Df	GFI	SRMR	RMSEA	CFI	TLI	NFI
Plan	302.9	118	**2.567**	0.56	0.100	0.218	0.76	0.72	0.66
Do	704.4	272	**2.590**	0.47	0.073	0.223	0.65	0.62	0.55
Check	344.4	161	**2.139**	0.58	0.086	0.189	0.80	0.77	0.70
Act	119.2	49	**2.432**	0.68	0.042	0.215	0.87	0.83	0.80

*Fitted models correlating errors for each construct.

Fig. 4 shows how the obtained factor loadings for the Do construct fluctuate between 0.76 and 0.97 and show R^2 values greater than 0.58.

Fig. 5 shows factor loadings between 0.77 and 0.99 for the Check items and R^2 values greater than 0.62.

Finally, Fig. 6 shows the Act items' factor loadings and R^2 values; the first parameter obtained loadings greater than 0.83 and 0.68, respectively. It should be noted that all the items of the different constructs proposed are statistically significant ($p - valor \leq .01$).

All these results allow us to unidimensionally assess that the items are strongly associated with each other and, thus, represent a single construct [64], which confirms their appropriateness for the measurement of each construct's factors. In addition, each first-order factor has at least three items, thus fulfilling the order condition [65].

Regarding the factors' covariance analysis, it can be said that all constructs yielded sufficient discriminant validity since, as shown in Table 6, the average variance extracted (AVE) values for each factor are greater than the R^2. This is confirmed by R results lower than 0.90 in all cases [61,64]. Another criterion used to determine discriminant validity was the heterotrait-monotrait correlations ratio (HTMT), in which the cut-off threshold for severe discriminant validity is 0.850 [66]. Therefore, discriminant validity is confirmed since the values obtained from this indicator (Table 6) are less than 0.85. However, because the Act construct only has one factor, obtaining its discriminant validity was unnecessary.

Additionally, two criteria were used to assess the convergent validity of all constructs: 1) the AVE criterion of Fornell & Larcker [61] (see Table 6) and 2) the items' standardized factor loadings (see Figs. 3–6). The former considers all factor loadings to be at least

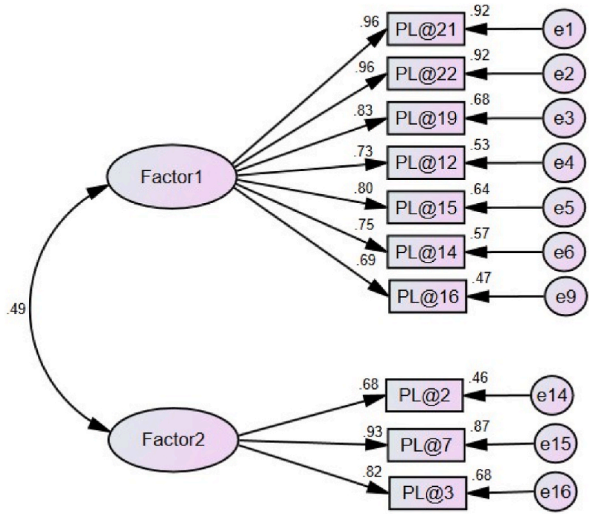

Fig. 3. Structural model for Plan.

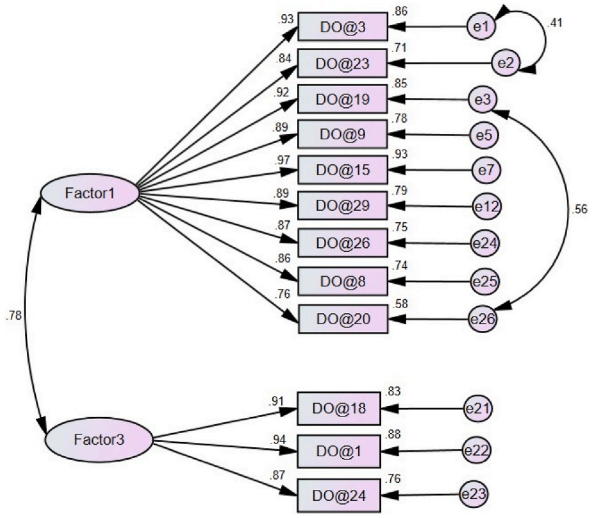

Fig. 4. Structural model for Do.

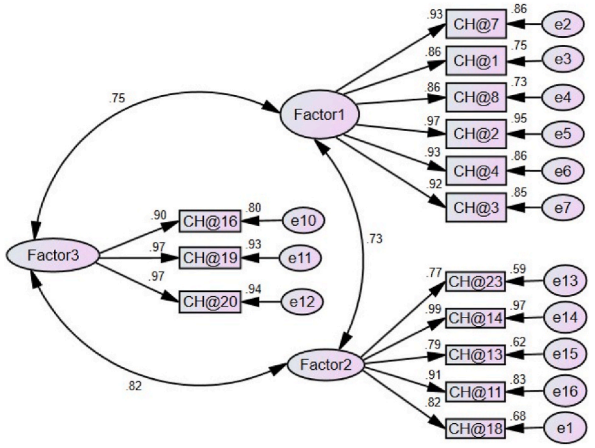

Fig. 5. Structural model for Check.

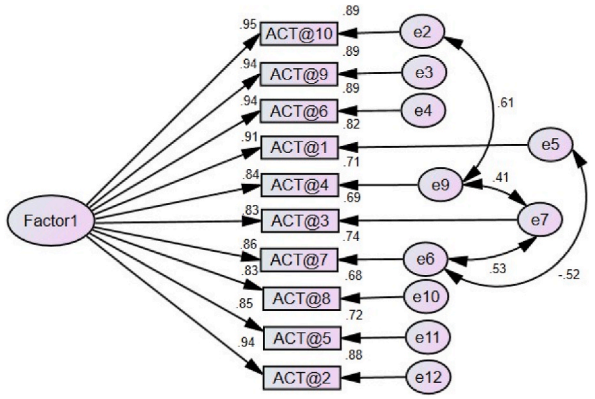

Fig. 6. Structural model for Act.

Table 6
Discriminant validity results.

Construct	Factor	AVE	R		R²		Discriminant validity AVEs > R²	Composite reliability	HTMT Factor 1	HTMT Factor 2	HTMT Factor 3
Plan	Factor 1	0.678	0.490		0.240		Yes	0.873			
	Factor 2	0.669					Yes	0.747	0.500		
Do	Factor 1	0.779	0.780		0.608		Yes	0.900			
	Factor 2	0.822					Yes	0.750	0.761		
Check	Factor 1	0.833	0.730		0.533		Yes	0.857			
	Factor 2	0.739		0.820		0.672	Yes	0.832	0.737		
	Factor 3	0.891		0.750[#]			0.563 Yes	0.750	0.736	0.802	
Act	Factor 1	0.791						0.909			

[#] R-value for factors 1 and 3 of the Check construct

0.5 and, ideally, 0.7 [64,67]. The latter suggests using an AVE >0.50 to demonstrate acceptable levels of validity [67]. Thus, factor loadings greater than or equal to 0.69 for every item and an average variance equal to or greater than 0.678 for every construct prove the convergent validity of all factors.

Next, the goodness-of-fit statistics of the measurement models are shown in Table 7. The chi-square results were not statistically significant in any of the constructs because this test is extremely sensitive to model fit and tends to reject it [68,69]; thus, other measures of fit are recommended [70]. As can occur with the normalized Chi-square by degrees of freedom (CMIN/Df), the obtained values ranged between 1.366 and 1.996 for the different constructs, this indicating an acceptable model fit for the experts' responses. In addition, Table 8 shows the results of the absolute and comparative indices for each construct. The values in bold mean that the acceptance parameters established for each index were met.

Other absolute fit index results were.

1) For the GFI, none of the results were considered to have the expected parameter even though the results lay between 0.72 and 0.79 for the different constructs, and Smith & Hoyle's [71] and Marcoulides & Schumacker's [72] suggest a value of 0.80 for acceptance.
2) Regarding the AGFI index, results of less than 0.636 were obtained; thus, it is considered that the models for each construct do not have the relative amount of variance and covariance to explain them; therefore, they do not fit the sample obtained. In addition, the sample size has a detrimental effect on the GFI and AGFI; therefore, they cannot be relied upon as independent indices [73]. However, in this case, obtaining a larger sample size was difficult due to the participants' characteristics.
3) As for the SRMS, because the results for most of the constructs lay below 0.08, they are considered acceptable models, except for that of the Plan construct, which exceeded this cut-off point.
4) The last absolute indicator, the RMSEA, obtained values above 0.10, this indicating a reasonable approximation error [74]; therefore, the models for each construct provide a mediocre fit [75].

On the other hand, the following were the comparative fit indices found.

1) Except for the Plan construct (0.87), CFI values above 0.90 were obtained. This indicates a satisfactory fit as Pina Portela [76] states that values between 0.8 and 0.9 are sufficient.
2) In the case of the TLI, the Plan construct presented marginal values below 0.90, while the rest of the constructs obtained values equal to or greater than 0.90, which demonstrates a good fit for these models.

Table 7
Final model fit results.

Final model											
Construct	**Chi-square χ^2**	**Df**	**P**	**CMIN/Df**	**GFI**	**AGFI**	**SRMS**	**RMSEA**	**CFI**	**TLI**	**NFI**
Plan	67.9	34	0.000	**1.996**	0.74	0.590	0.093	0.176	0.87	0.83	0.78
Do	88.1	51	0.000	**1.728**	0.72	0.585	**0.052**	0.151	**0.92**	**0.90**	0.84
Check	106.0	74	0.000	**1.433**	0.74	0.632	**0.059**	0.116	**0.94**	**0.93**	0.84
Act	42.3	31	0.000	**1.366**	0.79	0.635	**0.034**	**0.109**	**0.97**	**0.96**	**0.91**

*Fitted models correlating the errors for each construct.

Table 8
Reliability using Cronbach's alpha and McDonald's omega.

Construct	Initial instrument (87 items)				Final CIEMSE (46 items)				
	Dimensions	Items	Total of items	Cronbach's alpha	Factors	Items	Total of items	Cronbach's alpha	McDonald's omega
Plan		**1–22**	**22**	**0.966**			**10**	**0.915**	**0.915**
	1. Actions to address risks and opportunities	1–19	19	0.907	Factor 1	12, 14–16, 19, 21 & 22	7	0.935	0.942
	2. Ergonomics objectives and planning to achieve them	20–22	3	0.838	Factor 2	2,3 & 7	3	0.858	0.867
Do		**1–30**	**30**	**0.962**			**12**	**0.967**	**0.967**
	1. Support	1–18	18	0.947	Factor 1	3, 8, 9, 15, 19, 20, 23, 26 & 29	9	0.959	0.971
	2. Operation	19–30	12	0.910	Factor 2	1, 18 & 24	3	0.932	0.932
Check		**1–23**	**23**	**0.955**			**14**	**0.965**	**0.967**
	1. Monitoring, measurement, analysis, and performance evaluation	1–15	15	0.940	Factor 1	1-4, 7 & 8	6	0.965	0.969
	2. Internal Audit	16–18	3	0.768	Factor 2	11, 13, 14, 18 & 23	5	0.931	0.936
	3. Management review	19–23	5	0.899	Factor 3	16, 19 & 20	3	0.960	0.963
Act		**1–12**	**12**	**0.947**			**10**	**0.974**	**0.981**
	1. Incident, nonconformity, and corrective action	1–8	8	0.922	Factor 1	1–10	10	0.974	0.981
	2. Continual improvement	9–12	4	0.877					

3) In the case of the NFI, only the Act construct is considered to have an acceptable fit, while the rest of the constructs show values below 0.9, which can be due to the sample size issue.

3.3. Internal consistency (Cronbach's alpha and McDonald's omega)

Finally, the reliability of each construct in general and of each of the factors making up the EMS was determined through Cronbach's alpha (α) and McDonal's omega (ω) (see Table 8). Scores above 0.858 points for alpha and 0.867 points for omega are good indicators of the CIEMSE 's reliability. On the other hand, the number of dimensions or factors made up of different items was reduced from 9 to 8 compared to the initial instrument. The number of items for the final version of the CIEMSE is also different (See Appendix A).

4. Limitations of the research

This research aims to present a reliable and valid instrument to evaluate the ergonomics management system for the supply chain. However, there are certain limitations to the study that may affect the use and application of the proposed CIEMSE. First, the generalization of the results and the exploratory phase of the field research imposed restrictions because this CIEMSE was validated in the Spanish language and through a sample of experts from Latin America who experience the socio-cultural and economic reality in the region. There are also additional gaps to be considered, which Albrecht [77] has described as the need for more trained and certified specialists, as there is, indeed, a need to strengthen and certify training programs of Ergonomics. Thus, it was not easy to contact experts who both met the criteria required from different institutions in Latin America and were able to participate in the research. Moreover, time, money, and people resources were limited. There were also additional gaps related to the recognition of deficiencies in production processes and products that develop at a dizzying pace; the reason is that experts need an awareness and a permanent conquest of public and private spaces. In this context, physical ergonomics plays a central role in preventing musculoskeletal injuries, a significant problem in developing countries, where access to technology, sophisticated tools, and automatization is the privilege of large and powerful companies alone [78].

A further gap was the one identified by García-Acosta [79], who states that ergonomics has merely been inserted in the academic environment yet with little research and practical application and without a significant impact on the productive sectors. Additionally, in Latin American, the lack of regulations and penalization for not addressing ergonomic risk factors causes companies not to implement controls to improve working conditions or to comply only with the minimum legal aspects without going beyond what is required. On the other hand, no similar comparison instruments and variables exist in the current literature or other contexts, so criterion validation could not be assessed since this is the first instrument of its kind. Finally, because of the sample size, the data available to determine the validation and reliability of the instrument bears limitations in terms of statistical power, consistency, and magnitude of intervention effects. Therefore, for the instrument to maintain its relevant psychometric properties of validity and

reliability, it would need to be administered to a sample with the same contextual characteristics or undergo prior validation in the context in which it is to be implemented.

5. Discussions

This section will discuss the theoretical framework for the instrument's design and data analysis procedure, considering other authors' approaches. Because a discussion is presented for each of the stages proposed by this study, it is crucial to consider the CIEMSE's design method to obtain valid and valuable data during its implementation. Also, the literature shows consensus and similarities among the different stages and steps for designing an evaluation instrument, as will be described below.

In the first stage, the conceptual framework [80], or the information required for the design, is established based on the literature review [81–85], the established theoretical framework, and discussions with experts in the field under investigation [86,87]. Establishing such a framework is important as it provides a solid basis for understanding and defining the relevant variables of the research, which the instrument will go on to measure.

In the second stage, the preliminary items are drafted [80]. This process involves writing the items in such a clear, specific and relevant way that they can adequately measure each construct. The type of question (open or closed), the measurement scales [81,82] and the question order within the instrument [86,88,89] are all clearly defined, with an emphasis on the significance of these decisions in the research process.

In the third stage, Almenara [81], Trang et al. [90], Jahrami et al. [91], López-Belmonte et al. [82], Pedrajas & Carpio [83], and Oosterveld et al. [92] all conducted pilot tests to improve the writing and content of the items, thus ensuring face or content validity. This preparatory step is considered by Hassan et al. [93] as vital to the research process, as it can test research protocols, data collection instruments, sample recruitment strategies, and other research techniques in preparation to the identification of potential problem areas and deficiencies in both the instruments and the research protocol. Due to the crucial role it plays, this stage is commonly reported in papers.

The fourth stage consists of assessing the instrument's validity and reliability; these tests are prerequisites to ensuring the integrity and quality of a measurement instrument [89,94,95].Validity and reliability are the crucial quality standards behin the CIEMSE's construction. Terwee et al. [96] suggest performing tests for content validity, internal consistency, criterion validity, construct validity, reproducibility, longitudinal validity, responsiveness, floor and ceiling effects, and interpretability. On the other hand, Taherdoost [97] suggests carrying out four main validity tests: face validity, content validity, construct validity (discriminant and convergent validity), and criterion validity (predictive, concurrent, and postdictive validity).

It is important to note, however, that the type of questionnaire plays a significant role in determining the type of test to be conducted. Some tests could be mandatory, while others would only be recommended. Also, it is important to keep in mind that validity is a multifaceted concept. Different types of validity can be assessed depending on the instrument's context and purpose, and each type addresses a specific dimension of the instrument's appropriateness and purpose.

Another key factor, the instrument's reliability, ensures the extent to which the instrument consistently reproduces results. This quality is crucial when the instrument is used at different times or with other groups of people who are assumed to be similar. The more an instrument is validated, the more it will be trusted for result interpretation and conclusion drawing. The EFA analysis addresses content validity, whereas the CFA evaluates construct validity. Research by Martínez [98], Chandra & Kumar [99], Mishra & Banerjee [100], Luthra & Mangla [101], and Das [102] has consistently produced positive results, which confirms the reliability of these methods. In addition, the authors conducted an exploratory and confirmatory factor analysis to identify the structure of the instrument and verify its validity and reliability, as did López-Belmonte et al. [82], Pedrajas & Carpio [83], Sanchez-Lizarraga et al. [85], and Aguiar et al. [84]. Therefore, there is confidence in the methodology used in this research.

The originality of this research is supported by the literature review conducted as no similar data collection instruments using a continuous improvement approach, including the EFA and CFA, were found. Furthermore, the literature featured no EMS model or evaluation instrument implemented in this field that considered either PDCA or the dimensions based on the ISO 45001 standard as their primary constructs. However, the PDCA cycle model was indeed used by Ifadiana & Soemirat [28] to analyze the effects of integrated management system (IMS) implementation on work ergonomics and to find the influencing factors. These authors reported that the Plan construct had obtained the highest acceptance scores for the three types of respondents (managers, middle managers, and workers). In addition, they identified that middle managers have the most significant influence on the implementation of ergonomics, since they are the ones who carry out the IMS planning process, and that workers contribute by improving ideas and valuable suggestions. As for the top management level, they found that the planning process serves mainly as managerial decision making based on risk assessment. These results support the use of the PDCA cycle model and strengthen the idea of using middle and senior management responses to the CIEMSE to evaluate the CS's EMS.

Another research study conducted by Chang & Liang [103] also used the PDCA cycle model for an instrument to evaluate safety management systems in paint-manufacturing facilities. This work revealed the importance of the PDCA cycle model. The results showed that experts from the academia and government inspection agencies consider Do as the most important factor and Plan as the second in importance. On the other hand, safety consulting firms and the paint industry, who worked closely with field workers, thought the Plan factor was the most important and granted the Do aspect the second highest ranking. They also believed, based on their field experience, that good planning and a strong commitment from the senior management were the keys to successful safety management. These differences in the perception of the importance of the Plan and Do elements can be attributed to the different sectors in which the respondents were involved, their perspectives or interests, and their implementation experience. Nonetheless, despite the results obtained in the CFA for the Plan construct, and although Cresswell [104] justifies the importance of all four elements

in achieving continuous improvement, the findings still highlight the relevance of the Plan construct for management assessment.

On the other hand, Sanchez-Lizarraga et al. [85] and Ingason [105] concluded that the management's (leadership) commitment and direct participation as well as the employee's direct participation were key factors in the successful implementation of ISO 9001 quality management systems. What could be considered under ISO 45001 as leadership and worker participation should be incorporated into the design of the instrument as a fifth construct to be tested for EMS evaluation as those elements are fundamental in the creation of the EMS [29].

It is essential to highlight that although there are some similarities in the constructs used in the design of the evaluation instrument, the 15 dimensions used differ throughout the PDCA cycle model investigations found as these are measured by items designed carefully and exclusively from an EMS evaluation approach. Until now, no statistically validated instrument that uses at least four PDCA elements as a reference has been identified. Based on these facts, the findings reported in this article add new knowledge to the existing literature on EMS. In addition, this CIEMSE seeks to evaluate the EMS requirements and practices in each SC link individually under a philosophy of continuous improvement. This provides it with considerable originality since the research addressed the need to include this scope or evaluation approach in the entire SC and links.

Having a validated instrument to measure EM in the SC has essential implications in theory and practice; in the first field, it provides a solid framework to advance the knowledge of ergonomics management in the SC. In addition, it allows the development of new theories and hypotheses related to the impact on the productivity, health, and well-being of workers in the different links of the SC. Another advantage is the standardization of measurement, as it allows the comparison of results between different companies, sectors, and countries, promoting a global understanding of EM in SC operations. In the second field, the business environment enables organizations to improve safety, reduce costs, increase efficiency, and promote sustainable practices. This emphasis on sustainability is not just a business strategy but a moral responsibility. Using a validated instrument can help organizations fulfill this responsibility, impacting workers' well-being and the business's overall productivity.

6. Conclusions

In conclusion, Plan, Do, Check, and Act are the four constructs that serve as basis for EM measurement. These constructs are placed around interrelated dimensions or factors (items) to determine which ones are the most significant for factor analysis, which is one of the statistical techniques employed [49]. After submitting this new CIEMSE to such an analysis, this work concluded that the items are sufficiently associated with each other in each construct, which helped to reduce factors to perform the CFA. After the removal of items and factors, a final 46-item version of the CIEMSE was obtained (See Appendix A). This represents a reduction of 47.12 %, in which ten items belong to the Plan construct, twelve to Do, fourteen to Check, and ten to Act. All items are statistically significant at 95 %, their factor loadings are greater than 0.50, and $R^2 > 0.30$, even though not all structural model fit indices fit the sample data. Therefore, the objective of this research was reached as the instrument to evaluate the EMS of each supply chain link was statistically validated by experts in ergonomics, health and safety, management systems, and supply chain (logistics). In addition, the reliability of each construct and factor was determined by scores above 0.858 for Cronbach's alpha index and scores above 0.867 for McDonald's Omega index. This leads to the conclusion that this CIEMSE can be used to evaluate EMS in the SC through prior identification of the links in which respondents participate. In conclusion, there is evidence of the proposed instrument's statistical validity to support the research hypothesis.

Regarding the main limitations of this study, the context did impose some restrictions on the exploratory phase of field research because the CIEMSE was validated in the Spanish language and the sample experts are from Latin America, where the sociocultural and economic reality may differ from those of other parts of the world. Additionally, it was challenging to find experts in Latin America, particularly ones who would have the availability to participate in the research. In addition, the scarce inclusion of ergonomic risk factor awareness in the labor field and the lack of regulations and penalization imposed on organizations in Latin American countries, causes many companies not to implement controls that may improve working conditions or to comply with only the minimum legal aspects without going beyond what is required. The CIEMSE was developed in accordance with an extensive literature review, the continuous improvement model, and ISO 45001, which considers international implementation practices and requirements as an original instrument. In addition, there is need for more similar comparison parameters in the current literature or other contexts. The data available for the sample size was limited but sufficient to attribute validity and reliability to the instrument; they also play a crucial role in terms of statistical power, consistency, and magnitude of intervention effects. Considering all these aspects, for the CIEMSE to maintain its relevant psychometric properties of validity and reliability, its application should be restricted to samples with the same contextual characteristics; if it were to be used in new contexts, prior validation would be of essence. The above limitations create an opportunity for further research in different contexts and cultures at an international level so that contributions can be made to the study of ergonomics management in the supply chain.

CRediT authorship contribution statement

Iván Francisco Rodríguez-Gámez: Writing – original draft, Methodology, Investigation, Formal analysis. **Aide Aracely Maldonado-Macías:** Writing – review & editing, Investigation, Conceptualization. **Ernesto A. Lagarda-Leyva:** Validation, Software, Funding acquisition. **Juan Luis Hernández-Arellano:** Supervision. **Yordán Rodríguez:** Validation, Supervision, Software.

Data availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Ethics statement

The ethics approval number is CEI-2022-1-591, granted by the *Universidad Autónoma de Ciudad Juárez* (Autonomous University of Ciudad Juarez, UACJ) Research Ethics Committee.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

The final version of the CIEMSE**.**

Construct	Code	Items
Plan		**Regarding Ergonomics Management's PLAN process, the organization features the following:**
	PL@21	1. The objectives of ergonomics management have been updated in writing and made consistent with the policy. Also, they are now measurable or evaluable based on the applicable requirements and risk assessment results.
	PL@22	2. The approach to achieving the EM objectives has been determined.
	PL@19	3. Ergonomic risk assessment and necessary EM processes are planned, and the evaluation of their effectiveness is considered.
	PL@15	4. Risk prevention-related methodologies, the monitoring of affected workers, and the communication of new ergonomic-related legal requirements are included.
	PL@14	5. Risk assessment processes are considered: operations, daily decisions, and external aspects.
	PL@12	6. Ergonomic risk assessment methodologies and criteria are proactive and duly recorded.
	PL@16	7. Processes are established, implemented, and sustained to evaluate continuous improvement opportunities.
	PL@2	8. External factors such as regulations, norms, laws, and professions are considered.
	PL@7	9. The following areas are studied: opportunities for improvement in emergency management, risk analysis, ergonomic assessment, safety audit results, and communication and mitigation of risks.
	PL@3	10. Internal factors such as objectives, work resource and condition policies and strategies, organizational culture, standards, guidelines, and existing contracts are considered.
Do		**Regarding Ergonomics Management's DO process, the organization features the following:**
	DO@3	1. Workers' competence is developed to include their participation, knowledge, and necessary skills to identify ergonomic risks and hazards associated with their work.
	DO@23	2. The organization has established, implemented, and maintained procedures for eliminating hazards and reducing ergonomic risks.
	DO@15	3. The information records that EM requires are controlled to ensure they are available, legible, protected, and current (change control).
	DO@19	4. Process controls are established and implemented to increase ergonomics, eliminate hazards, or reduce risks throughout areas and activities.
	DO@29	5. Contract award tools or pre-qualification criteria are used to ensure the ergonomics performance of contractors in the workplace.
	DO@26	6. Supplies, equipment, raw materials, goods, and service procurement processes are established, implemented, and maintained to ensure EM compliance by identifying, evaluating, and eliminating hazards and reducing associated risks before their introduction into the workplace.
	DO@9	7. Workers are sensitized and made aware of ergonomic incidents, dangers, and risks as well as of preventive actions to be implemented.
	DO@8	8. Workers are sensitized and made aware of the ergonomics policy and objectives, their contribution to continuous improvement, and the implications of any non-compliance in management.
	DO@20	9. Operational controls are implemented to ensure workers' competence and work-person adaptation.
	DO@18	10. Information records include planning to address legal requirements, agreements, practices, and EM effectiveness evaluations.
	DO@1	11. All resources (human, natural, infrastructure, technology, and financial) are identified and provided to enable EM establishment, implementation, maintenance, and continuous improvement.
	DO@24	12. Supplies, equipment, raw materials, goods, and service procurement processes are established, implemented, and maintained to ensure EM compliance through the identification, evaluation, and elimination of hazards and the reduction of associated risks prior to its introduction into the workplace

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(*continued*)

Construct	Code	Items
Check		**Regarding Ergonomics Management's CHECK process, the organization features the following:**
	CH@7	1. Process monitoring and measurement is carried out through the effectiveness of the implemented controls or the need to modify or introduce new ones.
	CH@2	2. What needs to be monitored and measured is determined, as well as the necessary methods, the criteria for EM performance evaluation, and the time when the results must be analyzed, evaluated, and communicated.
	CH@8	3. Processes are monitored and measured to assess compliance with legal requirements, collective agreements, standards, codes, corporate policies, and regulations, as well as to identify any existing gaps.
	CH@4	4. Information records and results are properly kept as evidence of the monitoring, measurement, analysis, and performance evaluation.
	CH@1	5. The organization has set up, executed, and upheld processes for monitoring, measuring, analyzing, and evaluating performance.
	CH@3	6. The EM performance is evaluated to assess the effectiveness of its actions.
	CH@14	7. Compliance with legal and other requirements is evaluated considering evaluation frequency and methods, action implementation, degree of compliance, and record-keeping of evaluation results.
	CH@13	8. Processes to assess compliance with legal and other requirements are established, implemented, and maintained.
	CH@11	9. The organization monitors controls through tools such as interviews, record audits, and observations of work performed.
	CH@23	10. Information records are kept as evidence of top/middle management's check results.
	CH@18	11. The following considerations are important when conducting an internal audit: program assessment, auditor selection, audit conduction, result reporting and record keeping, and storage of audit information and results.
	CH@19	12. Top management checks EM at planned intervals to ensure its convenience, suitability, and continuous effectiveness.
	CH@16	13. Internal audits are carried out at planned intervals to guarantee compliance with the organization's EM requirements without setting aside the ergonomics policy and objectives established.
	CH@20	14. The management's checks assess compliance with previous checks, ergonomics policy, objectives, and resource performance.
Act		**In the organization, regarding Ergonomics Management's ACT process:**
	ACT@10	1. Improvement actions are taken considering EM analysis as well as performance evaluation results, internal audits, and management checks.
	ACT@9	2. The convenience, suitability, and effectiveness of EM is continuously improved.
	ACT@6	3. The effectiveness of the actions taken to eliminate or reduce incidents or nonconformities is reviewed.
	ACT@2	4. The necessary actions are implemented to achieve the expected results.
	ACT@1	5. Opportunities for improvement are identified to achieve the expected results.
	ACT@5	6. Ergonomic risks are assessed with workers' participation to identify and eliminate the root cause of incidents or non-conformities.
	ACT@3	7. Processes are in place to report, investigate, and take action to identify and manage incidents and nonconformities.
	ACT@7	8. Information records are kept as evidence of incidents or non-conformities, actions taken, results, and effectiveness.
	ACT@4	9. Any incidents or non-conformities are addressed promptly.
	ACT@8	10. The information recorded is communicated to workers, their representatives, and other interested parties.

Appendix B

Exploratory factor analysis.

Items	Rotated Component Matrix							Component Matrix
	Factor Plan		Factor Do		Factor Check			Factor Act
	1	2	1	2	1	2	3	1
PL@21	0.956							
PL@22	0.929							
PL@19	0.833							
PL@15	0.807							
PL@14	0.764							
PL@12	0.666	0.418						
PL@16	0.630							
PL@2		0.833						
PL@7		0.830						
PL@3		0.762						
DO@3			0.874					
DO@23			0.837					
DO@15			0.835	0.482				
DO@19			0.831	0.404				
DO@29			0.824					
DO@26			0.822					
DO@9			0.791	0.419				
DO@8			0.760					
DO@20			0.660					
DO@18				0.954				
DO@1			0.460	0.788				

(*continued on next page*)

(*continued*)

Items	Rotated Component Matrix							Component Matrix
	Factor Plan		Factor Do		Factor Check			Factor Act
	1	2	1	2	1	2	3	1
DO@24			0.429	0.739				
CH@7					0.843			
CH@2					0.841			
CH@8					0.811	0.538		
CH@4					0.796		0.415	
CH@1					0.784			
CH@3					0.751		0.453	
CH@14						0.816	0.432	
CH@13						0.766		
CH@11						0.715	0.446	
CH@23						0.670		
CH@18						0.645	0.484	
CH@19							0.836	
CH@16							0.804	
CH@20						0.429	0.780	
ACT@10								0.950
ACT@9								0.942
ACT@6								0.932
ACT@2								0.928
ACT@1								0.907
ACT@5								0.871
ACT@3								0.871
ACT@7								0.868
ACT@4								0.864
ACT@8								0.804

Extraction method: Unweighted least square.
Rotation Method: Varimax.

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