An Integrated Approach of Multiple Correspondences Analysis (MCA) and Fuzzy AHP Method for Occupational Health and Safety Performance Evaluation in the Land Cargo Transportation

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Abstract. Land cargo transportation is one of the components of the logistics chain with high impact on economic and social development worldwide. However, problems such as top logistics costs, deficiencies in transportation infrastructure and the failure to adopt good operating practices in aspects such as quality, environment, and occupational safety and health affect the ability of companies to comply with the agreements, requirements, and regulations of the clients and other interested parties. One of the most relevant problems for the sector is associated with the high accident rates that make this medium less advantageous compared to other means of transport with impact on operational costs, on logistics indicators, on compliance with legal regulations and customer satisfaction. However, although there are legal standards and management standards in occupational safety and health, evaluating performance can become a difficult and subjective process, due to the complexity of the land cargo transportation and the different interest groups involved. Besides, there is little information in the literature that provides solutions for the industry. Therefore,

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this document presents an integrated approach between multi-criterion decision making models (MCDM) and the Multiple Correspondences Analysis (MCA) to facilitate the evaluation and improvement of occupational health and safety performance, with a logical process, objective, robust and using both qualitative and quantitative techniques, with real application in the land cargo transportation sector. First, the multivariate method of Multiple Correspondences Analysis (MCA) was used for the evaluation of a sample of companies in the industry, considering the factors and sub-factors identified in the first stage and performing correlational analyzes among the variables. Subsequently, a multicriteria decision-making model was designed to determine the factors and sub-factors that affect occupational health and safety performance through the technique of the Fuzzy Analytic Hierarchy Process (FAHP). Finally, improvement strategies are proposed based on the approaches suggested in this document.

Keywords: Fuzzy Analytical Hierarchy Process · Fuzzy AHP · Multicriteria decision making · MCMD · Factorial analysis · Multiple Correspondence Analysis (MCA) · Occupational health and safety · ISO 45001 · Land cargo transportation · Cargo logistics · Performance evaluation

1 Introduction

Land cargo transportation represents one of the links in the logistics chain of great importance at the regional, national and global levels, due to its impact not only at an economic level but a social level [1]. In this sense, statistics show that the road freight transport sector represents 90% of the movements of goods in countries such as Argentina, Spain, Greece, South Korea, Bulgaria, Canada, China, Colombia, Denmark, Finland, France, Italy. In other countries such as the United Kingdom, the Czech Republic, and South Africa, land transport concentrates between 75% and 80% of traffic. Besides, in Germany, Austria, Belgium, Brazil, Croatia, the United States, India, Japan, the Netherlands, it is estimated that more than 50% of the modal distribution is by land [2].

However, this sector shows operational deficiencies that affect aspects such as productivity, competitiveness, and safety compared to other transport services. In this regard, Dinero Magazine [3], highlights the problems of the land transport sector, which affect its capacity to adapt to new challenges such as globalization, customer demands, legal regulations, and society. Among the problems identified is the deficiency in the implementation of management standards to continuously improve their performance and comply with current regulations in areas such as quality, safe trade, environment, safety, and occupational health. In this sense, this last aspect of safety and health at work is of great importance due to the complexity of the land cargo transportation and the surveillance and control by official bodies, customers and others involved in the logistics chain.

According to the research of International Labor Organization [2], the land transport sector presents different safety and occupational health problems, such as a high risk of traffic accidents, psychosocial factors associated with long working hours, stress, drugs, and alcohol. Concerning the conditions of the vehicle conditions, external factors that include the state of the roads, physical hazards, violence, dangerous work situations and internal factors related to the methods of enlistment and location of cargo, traffic infractions, among others, are problems that should be considered. These health and safety risks at work can directly affect other users of roads, traffic and public safety in general, as well as operating costs for companies derived from accidents at work and occupational diseases. Also, an increase in the lead time and inventory volume, which generate delays, operational inefficiencies, economic losses, loss of reputation and decrease in competitiveness, leading to a negative impact on the economic and social development of a country [4].

These aspects justify the carrying out of research that contributes to the development and implementation of management methodologies, focused on the prevention of accidents and occupational diseases in the land cargo transportation. In this regard, we found different investigations carried out for the transport sector in general, oriented towards the analysis of root causes for accidents and risk management. Besides, in the literature review, we found several studies with the application of the Multicriteria Decision Methods (MCDM) and Multiple Correspondence Analysis (MCA). However, the development of studies in the use of hybrid methodologies based on MCDM and MCA for Occupational Health and Safety Performance Evaluation in Land Cargo Transportation sector is still minimal and with scarce information.

In this work, we propose an integrated methodology based on the application of the Multicriteria Decision Methods based on Multiple Correspondences Analysis (MCA) approach and Fuzzy Analytic Hierarchy Process (FAHP) to evaluate the Occupational Health and Safety performance in the land cargo transportation sector, analyzing the case study of Colombia, under a quantitative methodological, of descriptive and correlational scope.

The design of the methodology is based on the approach of the ISO 45001 standard and the PDCA (Plan-Do-Check-Act) methodology, through the design of a performance evaluation model and its application in 25 companies in the sector.

First, the Multiple Correspondence Analysis (MCA) was used, after validation of the reliability and significance of the evaluation instrument, to classify the companies in differentiated groups considering their performance in occupational health and safety. Likewise, to correlate the influence of critical variables such as seniority, size, number of employees with the level of performance, with which improvement strategies are defined by companies in the sector analyzed. Then, the Fuzzy Analytic Hierarchy Process (FAHP) was applied to reconcile human subjectivity and the multiple criteria in the evaluation process. In this regard, FAHP is used to estimate the global and local weights of criteria and sub-criteria under uncertainty in the ponderation.

The results show that the methodology allows not only to evaluate the performance of companies through significant key variables, but also critical variables can be identified that affect the management, in this case, the implementation and improvement for occupational safety and health security, which is reflected quantitatively and through 4 groups of companies according to their performance. Likewise, the findings show that aspects such as size, seniority, and the national or international scope of the companies, affect the level of performance in Occupational safety and health. Considering the previous point, this integrated methodology facilitates the decision-making process Managers for the improvement in the management of health and safety at work, through the use and interaction of computational tools and statistics.

2 Approaches of MCDM and Multivariate Methods for Occupational Health and Safety Performance Evaluation: A Brief Literature Review

In spite of the advances of the last years, the land cargo transportation, presents high accident rates, in comparison with other modalities of transport like the rail transport, maritime transport, and air transport at world-wide level. In Colombia, accident statistics exceed both the number of accidents and the number of deaths recorded in other transport systems [5]. The leading causes of accidents and occupational diseases are related to insecure acts by drivers, faults in vehicles and transportation systems, poor road conditions, high workloads and stress [2], affecting significantly, the quality-life of workers, the competitiveness of transportation sector and, consequently, the value chain of production and services of many organizations.

In this regard, the identification of risks and dangers, the control measures at the source, the environment, and the worker, procedures and protocols, education and awareness, among other aspects, are vital to generate a culture of prevention of accidents and occupational diseases. In this sense, the management of occupational safety and health, allows an employer or independent undertakings create an optimal relationship between the economy and security while respecting the employer's responsibility for protection [6].

In recent years, the use of different regulations and standards to support the implementation of occupational health and safety management has become increasingly common due to the demands of the government, customers and other stakeholders in the chain of logistics value. At an international level, standards such as the OHSAS 18001, and more recently, the ISO 45001 standard, help organizations improve their safety and health performance at work to prevent injuries and deterioration of workers' health and to provide places of safe and healthy work [7].

In Colombia, these standards have facilitated the creation of legal regulations applicable to the cargo transport sector such as the Decree No 1072 of 2015. This normativity establishes and regulates the Occupational Health and Safety Management for companies. In the same way, the Resolution 1565 of 2014 (it contains the guidelines for the implementation of the Strategic Plan of Road Safety to reduce the accident rate), and Resolution No 0302 of 2019 (this legislation lays down the rules for the compliance of minimum standards in Occupational Health and Safety in organizations).

All such considerations have led to the development of different studies that contribute to the development and implementation of management methodologies, focused on the prevention of accidents and occupational diseases in the transport sector. In this regard, we found different research oriented towards the analysis of risk management in maritime ports using Fuzzy techniques [8], analysis of transport risk by checking probabilistic models [9], develop approach of root causes for accidents in the maritime industry [10], and use of techniques to increased safety and operability of inland terminals for containers with dangerous goods [11].

In the land cargo transportation, the focus of the identified studies is aimed determining the safety risks management in the road transport [6, 12–14], to analyze the elements that affect the successful implementation of occupational health and safety management. Likewise, there are other objectives such as identifying the literature review that support the safety management for heavy vehicle transport [15], recognizing the safety and health perceptions in work-related transport activities in industries [16], and evaluate the initial conditions for implementation of the Integrated Management System based on quality, health and safety [1]. All these studies highlight the need to continually identify and evaluate performance and propose improvement strategies to reduce accidents and work-related illnesses in the land transport sector, so the evaluation of overall performance is shown as an alternative to investigate with greater depth.

Regarding the object of this research, we found in the literature review evidence of studies oriented to apply the Multicriteria Decision Methods (MCDM) in occupational health and safety management (OHS). In this regard, one of the most recent studies conducts a critical state-of-the-art review of OHS risk assessment studies using MCDM-based approaches, includes fuzzy versions of MCDM approaches applied to OHS risk assessment [17]. The results of this study, which analyzed a total of 80 papers cited in high-impact journals, demonstrated the growing trend in the use of MCDM in the evaluation of risks, especially in the use of FAHP-based approaches, with application mainly in the manufacturing sector. On the other hand, the potential to continue developing methods of evaluation in occupational health and safety based on MCDM in an integrated way with different approaches was also identified.

On the other hand, we review the literature in the use of Multivariate Correspondence Analysis in Occupational Health and Safety. In this sense, we found several works with the application of the MCA method in the identification of areas of intervention for public safety policies using multiple correspondence analysis [18], use of multiple correspondence analysis and hierarchical clustering to identify incident typologies about the biofuel industry [19]. We also found other studies about pattern extraction for high-risk accidents in the construction industry: a data-mining approach [20], and decision support system for safety improvement using multiple correspondence analysis, t-SNE algorithm and K-means clustering [21].

However, the use of the integrated approaches of Multiple Correspondences Analysis (MCA) and MCDM such as Fuzzy AHP does not have an extended application, especially in the occupational health and safety performance evaluation in the land cargo transportation. Therefore, this research contributes to the scientific literature and provides a hybrid methodology for overall performance evaluation in occupational health and safety management and provides to managers procedures and techniques to generate a culture of prevention and healthy environments, through strategic alignment, driving the behavior and performance of people towards the achievement of the strategic objectives of land cargo transportation [22].

3 Proposed Methodology

The proposed approach aims to evaluate the overall performance in occupational health and safety management in the land cargo transportation sector by the integration of the Multiple Correspondence Analysis (MCA) and the Fuzzy Analytic Hierarchy Process (FAHP). In this regard, the methodology is comprised of four phases (refer to Fig. 1):

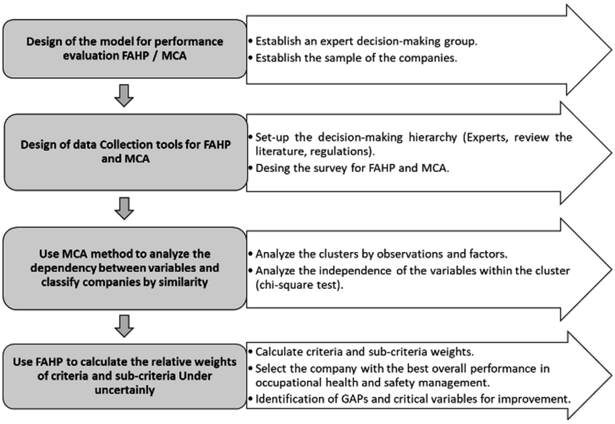


Fig. 1. Methodological approach for evaluating the overall performance in occupational health and safety management in the land cargo transportation

- **Phase 1 (Design of the model for performance evaluation FAHP/MCA):** A decision-making group is chosen based on their experience in occupational health and safety. The experts will be invited to be part of the decision-making process through Fuzzy Analytical Hierarchy Process (FAHP) technique. Subsequently, a sample of companies of the land cargo transportation was selected for the application of the MCA method.
- **Phase 2 (Design of data collection tools for FAHP and MCA):** In this step, the criteria and sub-criteria are established to set up a decision hierarchy considering the personal opinion of the expert decision-makers, the literature review and regulations in occupational health and safety management [23]. Then, the surveys for the application of the FAHP and MCA methods were designed.
- **Phase 3 (MCA application):** In this step, the Multivariate Correspondence Analysis (MCA) method was implemented to analyze from a graphical point of view the dependency and independence relationships of a set of categorical variables and the classification of observations or individuals in clusters considering the similarity in their responses for each variable (described in Sect. 3.2). For this purpose, we designed a survey considering the personal opinion of the expert decision-makers, literature review and regulations. Then, collecting of data set of 25 companies and finally, applied the MCA method using R 3.5.0 software.
- **Phase 4 (FAHP application)**: FAHP is used to estimate the global and local weights of criteria and sub-criteria under uncertainty in the ponderation. In this

phase, the experts were invited to perform pairwise comparisons, which are subsequently processed following the FAHP method, as detailed in Sect. 3.1. Also, in this phase, GAPs and critical variables were identified with the goal of improving the overall performance in the evaluation of occupational health and safety management [1, 24, 25].

3.1 Fuzzy Analytic Hierarchy Process (FAHP)

Fuzzy AHP is an extension of Analytic Hierarchy Process (AHP) proposed by Thomas L. Saaty as an integrated methodology between the AHP and Fuzzy Logic with the aim of improving decision-making process since inability of AHP to deal with the imprecision and uncertainty of human judgments and with multiple criteria in the pair-wise comparison process [26, 27]. In this regard, according to Ortiz-Barrios et al. [28], the fuzzy logic theory was introduced due to its capability of representing imprecise data. Fuzzy AHP uses a range of value to incorporate the decision maker's uncertainty [29, 30].

In FAHP, the paired comparisons are represented in a matrix using fuzzy triangular numbers [31–33] as described below (Refer to Table 1). Considering the findings from the literature review, a reduced AHP scale has been adopted by the decision makers when making comparisons [28].

Table 1. Linguistic terms and their fuzzy triangular numbers

Reduced AHP scale	Definition	Fuzzy triangular number
1	Equally important	[1, 1, 1]
3	More important	[2, 3, 4]
5	Much more important	[4, 5, 6]
1/3	Less important	[1/4, 1/3, 1/2]
1/5	Much less important	[1/6, 1/5, 1/4]

The steps of the FAHP algorithm as follows:

– Step 1: Perform pairwise comparisons between criteria/sub-criteria by using the linguistic terms and the corresponding fuzzy triangular numbers established in Table 1. With this data, a fuzzy judgment matrix $\tilde{A}^k\left(a_{ij}\right)$ is obtained as described below in Eq. 1:

$$\tilde{A}^k = \begin{bmatrix} \tilde{d}^k_{11} & \tilde{d}^k_{12} & \cdots & \tilde{d}^k_{1n} \\ \tilde{d}^k_{21} & \tilde{d}^k_{22} & \cdots & \tilde{d}^k_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{d}^k_{n1} & \tilde{d}^k_{n2} & \cdots & \tilde{d}^k_{nn} \end{bmatrix} \tag{1}$$

$\tilde{d}^k_{ij}$ indicates the *kth* expert's preference of *ith* criterion over *jth* criterion via fuzzy triangular numbers.

- Step 2: In this phase, GAPs and critical variables were identified, and improvement strategies were defined with the goal of improving the overall performance in the evaluation of occupational health and safety management.
- Step 3: In the case of a focus group, the judgments are averaged according to Eq. 2, where K represents the number of experts involved in the decision-making process. Then, the fuzzy judgment matrix is updated as shown in Eq. 3.

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{K} \tilde{d}_{ij}^{k}}{K} \tag{2}$$

$$\tilde{A} = \begin{bmatrix} \widetilde{d_{11}} & \cdots & \widetilde{d_{1n}} \\ \vdots & \ddots & \vdots \\ \widetilde{d_{n1}} & \cdots & \widetilde{d_{nn}} \end{bmatrix} \tag{3}$$

- Step 4: Calculate the geometric mean of fuzzy judgment values of each factor by using Eq. 4. Here, $\tilde{r}_i$ denotes triangular numbers.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij} \right)^{1/n}, \ i = 1, 2, \ldots, n \tag{4}$$

- Step 5: Determine the fuzzy weights of each factor $(\tilde{w}_i)$ by applying Eq. 5.

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \ldots \oplus \tilde{r}_n)^{-1} = (lw_i, mw_i, uw_i) \tag{5}$$

- Step 6: Defuzzify $(\tilde{w}_i)$ by performing the Centre of Area method [34] via using Eq. 6. M_i is a non-fuzzy number. Then, normalize M_i via applying Eq. 7.

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \tag{6}$$

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \tag{7}$$

3.2 Multivariate Correspondence Analysis (MCA)

The Multiple Correspondence Analysis (MCA) is a statistical technique used in the analysis of multivariate exploratory data. According to Rueda and Balmaceda [35], its objective is to reduce the dimension of the space of the observed characteristics in a small number of variables related to the set of variables and to represent in a factorial plane the maximum information contained in a Table of Burt (TB). This process is done to obtain typologies of the rows or typologies of the columns that are related to each other [35], facilitating the identification of groups of observations or groupings considering the correspondence in their responses and the variables that affect their classification. From there the correspondence term is justified, that is, the technique that seeks that the rows or columns correspond in information. The MCA is based on the direct results of matrix theory. It mainly uses the decomposition of a matrix in singular values.

In this regard, according to [21], "Multiple Correspondence Analysis. MCA uses a data matrix as its input to develop point clouds where data are clustered by similarity. Let N be the number of individual records (i.e. row) and Q be the number of categorical variables (i.e. column) and J_q be the number of categories for q^{th} categorical variable, then the total categories for all variables are, $J = \sum_{q=1}^{Q} J_q$ 'N multiplied by J' forms the indicator matrix (A) with elements aij such that aij = 1 if = i^{th} observation contains the category, otherwise aij = 0". The mathematical procedure of MCA is given as follows [21].

- Step 1: The indicator matrix is transformed to matrix Z such that each element z_{ij} of Z is derived as $z_{ij=\frac{a_{ij}}{W}}$ where W is the total count $W = \sum_{\mathrm{i}=1}^{\mathrm{N}} \sum_{\mathrm{j}=1}^{\mathrm{J}} a_{ij}$. Z is also known as the correspondence matrix.
- Step 2: Row and column masses of Z, denoted by r_i and c_j respectively, are obtained by summing up the row and column point profiles as described below in Eqs. 8 and 9:

$$r_i = \sum_{j=1}^{J} z_{ij} \tag{8}$$

$$c_j = \sum_{i=1}^{N} z_{ij} \tag{9}$$

  Where i = 1, 2, ………, N and j = 1, 2, ……… J.
- Step 3: Row and column profiles, denoted as r and c are the vectors containing the row and column masses as an individual element, respectively.
- Step 4: Using singular value decomposition (SVD) principles, U, Dα, and VT can be calculated from the matrix D where (refer to Eq. 10)

$$D = D_r^{-1/2}\left(Z - rc^T\right)D_c^{-1/2} \tag{10}$$

  D_r and D_c are diagonal matrices having r_i and c_j as diagonal elements. U, V are the orthogonal matrices of N × N and J × J dimensions respectively, and D_α is diagonal matrix of N × J dimension.
- Step 5: Principal inertia of the retained components K = (J − Q) are in the diagonal of $D_\lambda = D_\alpha^2$. Total inertia is the total sum of squares of the diagonal elements of D_λ.
- Step 6: For obtaining correspondence plot of row and column categories in low dimensional space, SVD will give us first coordinates as given below in Eq. 11:

$$W = D_r^{-\frac{1}{2}} U D_\lambda^{\frac{1}{2}}, \quad X = D_c^{-\frac{1}{2}} V D_\lambda^{\frac{1}{2}} \tag{11}$$

  Where W and X are the coordinate matrices of individual observations and variables with dimension K, respectively.

The maximum possible number of MCA dimensions are calculated by the difference between the sum of variable categories and the number of variables. The number of dimensions to retain can be determined by calculating inertia, which is a measure of variance explained and choosing from the cumulative percentage of variance explained. Further, to aid the visualization, the first two dimensions are usually considered for interpretation. The coordinates of each category on selected dimensions are displayed to determine similarity amongst categories.

4 Application of the Integrating Proposed Approach

4.1 Design of the Model for Performance Evaluation FAHP/MCA

In this stage, it began with the selection of companies belonging to the land cargo transportation sector. This allowed, in the first place, the choice of some representatives of these companies as experts for the validation process of the criteria and sub-criteria through the FAHP technique and then, for the application of the MCA method through a survey.

In this regard, the survey was applied to a sample of 25 companies of the land cargo transportation sector in Colombia using Eq. 12 for the calculation of the sample size (p = 0,5; q = 0,5; e = 0,05; k = 1.96; N = 27).

$$n = \frac{k^2 * p * q * N}{(e^2 * (N - 1)) + k^2 * p * q} \tag{12}$$

Subsequently, a decision-making group was selected with the aim of validating the criteria and sub-criteria through the application of FAHP technique, for the overall performance evaluation in occupational health and safety management given they expertise in these topics.

This project was presented to the selected companies. The chief executive of each organization gave informed consent for participation. Then, the expert team was selected. The selection process of these participants began with the identification of decision-maker profiles. In this regard, four types of experts were found to be meaningful for the decision-making process: leaders of occupational health and safety departments of the selected companies (three experts were selected, one expert representing small companies, and one expert from medium-sized companies and one representative from large companies), two experts consultors in health and safety management, and two representatives of academic sector linked to the occupational health and safety in companies. The team of experts was comprised of:

- Participants 1, 2 and 3 are industrial engineers with specialization in occupational health and safety and minimum 5 years of experience as a leader in occupational health and safety departments. Participant 1 in representation of small companies, Participant 2 as part of medium-sized companies and Participant 3 in representation from large companies.

- Participants 4 is an industrial engineering with specialization in Occupational Health and more than seven years of experience in the management of health and safety programs in companies as a leader of department and as a consultant.
- Participant 5 is a professional in occupational health and safety with a master's degree in Management Systems and 10 years of experience as a consultant in both private and public organizations in the diagnostic, design implementation and improve health and safety programs in companies.
- Participants 6 is industrial engineering, specialist in occupational health and Auxiliary Professor with knowledge and 10 years of experience in health and safety in work, regulations and standards in occupational health and safety management (OHS), risk assessment, and industrial hygiene.
- Participant 7 industrial engineering, specialist in quality and engineering management, master's degree in industrial engineering, Auxiliary Professor, and Associated Research with experience and knowledge in occupational health and safety management, multivariate methods and multi-criteria models for performance evaluation. The industrial engineer acted as a facilitator to take over the judgment process.

Specifically, the facilitators established a decision-making hierarchy that would assist the researchers and practitioners in identifying and predicting the criteria and subcriteria in the occupational health and safety management evaluation. In addition, they trained the team members to undertake paired comparisons employing the FAHP. Complementary to these activities, the participants were also invited to enroll in the decision-making team based upon their expertise to provide precise information about the evaluation criteria, which should be included in the decision process to assess the performance in occupational health and safety in companies.

The decision-making group identified four criteria (C1, C2, C3, and C4) and 23 sub-criteria (S1, S2… S23) to evaluate the performance in occupational health and safety management in companies of land cargo transportation. The criteria and sub-criteria were established based on the personal experience of experts, the regulations applicable to the cargo transport sector such as the Decree No 1072 of 2015 (this normativity establish the and regulates the occupational health and safety management for companies), Resolution 1565 of 2014 (it contains the guide-lines for the implementation of Strategic Plan of Road Safety to reduce the accident rate), Resolution No 0302 of 2019 (this legislation lays down the rules for the compliance of minimum standards in Occupational Health and Safety in organizations), requirements of the international standard ISO 45001 [7] and the pertinent scientific literature. The experts took into account all the aforementioned health and safety regulations, and the literature review presented by the experts of the academic sector in order to provide an MCDM model responding to the current needs of land cargo transportation.

The multi-criteria hierarchy was then verified and discussed during multiple sessions with the expert decision-making team to establish if it was accurate and comprehensible. The final decision model is presented in Fig. 2.

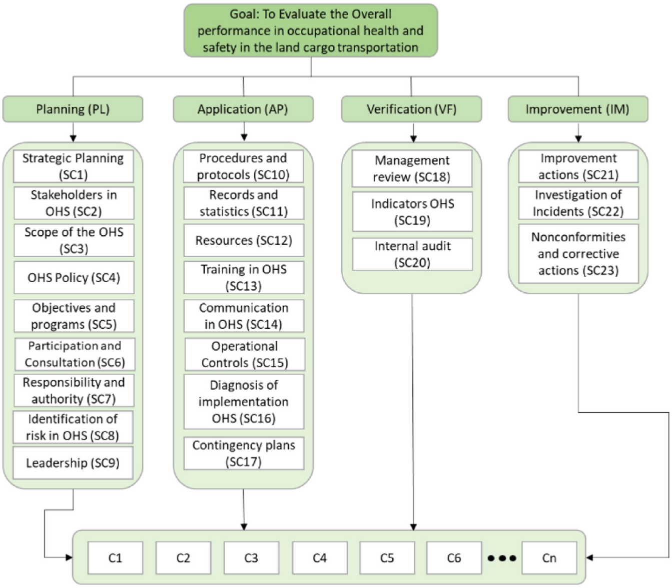


Fig. 2. Multi-criteria decision-making model to evaluate the overall performance in occupational health and safety management in the land cargo transportation

Particularly, the aforementioned criteria and sub-criteria were labeled and described as stated in Table 2.

Table 2. Description of criteria

Criterion (C)	Subcriteria (SC)	Criterion description
Planning (C1)	Strategic planning (SC1) Stakeholders in OHS (SC2) Scope of the OHS system (SC3) OHS Policy (SC4) Objectives and OHS programs (SC5) Participation and consultation (SC6) Responsibility and authority in OHS (SC7) Identification of risks in OHS (SC8) Leadership (SC9)	Is defined as the capacity of the company to establish the strategic elements that allow proactive and prospective planning of the company in occupational health and safety management and the degree to which the OHS system meets the government regulations and stakeholder's requirements
Application (C2)	Procedures and protocols (SC10) Records and statistics (SC11) Resources (SC12) Training in OHS (SC13) Communication in OHS (SC14) Operational Controls (SC15) Diagnosis of implementation OHS (SC16) Contingency plans (SC17)	Considers the implementation of procedures, protocols, registers, and statistics, for operational control of processes in occupational health and safety. This criterion also taking into account the resources (infrastructure, technology, financial, human), training and communication activities necessary to the operation of the management system in health and safety

(*continued*)

Table 2. (*continued*)

Criterion (C)	Subcriteria (SC)	Criterion description
Verification (C3)	Management review (SC18) Indicators OHS (SC19) Internal audits (SC20)	This criterion measures the company capability to evaluate its performance in order to achieve the expected results of the system, through mechanisms such as review by management, indicators, and audits in occupational health and safety
Improvement (C4)	Improvement actions (SC21) Investigation of incidents (SC22) Nonconformities and corrective actions (SC23)	Criterion considers the company's ability in the implementation of recurrent activities to improve performance in occupational health and safety management in coherence with the OHS policy and the objectives in OHS

4.2 Design of Data Collection Tools for FAHP and MCA

For the data collection, a survey for evaluation of conditions in occupational health and safety management was designed based on the personal experience of the selected experts, the occupational health and safety regulations, and the literature review. This instrument consists of two components, as shown in Fig. 3. In the first item, general aspects or profile of the companies were analyzed, such as antiquity, size, type of company, and export orientation. In the second item, the objective is to diagnose the companies of the land cargo transportation based on the criteria and sub-criteria validated with the experts concerning the application of occupational health and safety management, to identify the critical variables in the evaluation of the companies and recognize the clusters of companies taking into account the similarities in their answers with the use of MCA methodology (refer to Fig. 3). This item consists of four components, each with questions associated with the sub-criteria within each criterion as shown in Fig. 2. Each question is rated by the companies taking into account the following evaluation scale adapted from [36] (refer to Table 3).

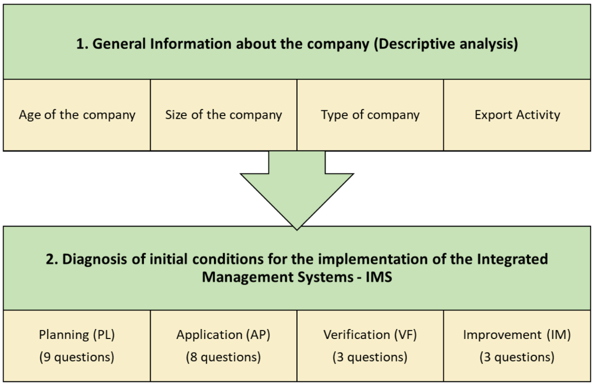


Fig. 3. Structure of the survey for diagnosis of the occupational health and safety management (MCA methodology)

Table 3. Rating scales

Rating scale	Level	Description
1	Without application	Not implemented
2	Basic	There are plans to implement it at the related levels
3	Advanced	It is beginning to be implemented at related levels
4	Expert	It is applied in most of the related levels of the company
5	Mature	It is applied at all levels of the company

Likewise, a data-collection instrument (refer to Fig. 4) was created to gather the paired comparisons performed by the expert team. Then, by using Eqs. 1–7, criteria and sub-criteria weights were determined. For each pairwise judgment it was asked: Concerning goal/factor, how important is each element on the left over the item on the right? The participants answered by using the scale described in Table 1. This process was then repeated until completing all the judgments. Mainly, the design of this instrument contributed to minimizing discrepancies and lack of comprehension. Additionally, it excluded intransitive comparisons during the decision-making process.

According to your experience with respect to "Improvement" sub-criterion, how important is each sub-criterion on the left concerning the sub-criterion on the right when evaluating the overall performance in occupational health and safety management in companies of land cargo transportation?

		1	2	3	4	5		
Improvement actions	is	○	○	○	○	○	Important than	Investigation of incidents
Improvement actions	is	○	○	○	○	○	Important than	Nonconformities and corrective actions
Investigation of incidents	is	○	○	○	○	○	Important than	Nonconformities and corrective actions

① Much less ② Less ③ Equally ④ More ⑤ Much more

Fig. 4. Data-collection instrument implemented for FAHP judgments

4.3 Application of Multivariate Correspondence Analysis (MCA)

After collecting data, the application of the MCA method was carried out, using software R version 3.5.1. In this phase, the factor maps were obtained to show the relative positions of the companies according to the factors (criteria) and the variables (sub-criteria) identified by the experts in phase 1, to evaluate the performance in Occupational health and safety in the land cargo transportation sector. The factor maps classified the companies into clusters, taking into account the similarity in the responses associated with each criterion and sub-criteria in the questionnaire for the application of MCA method, as shown in Figs. 5a, b, c, and d. The two dimensions of the questionnaire, collect 27.33% of the variability in the answers for the planning criterion, 40.18% for the factor of application, 38.42% for the criterion of verification and 44.11% for the factor of improvement.

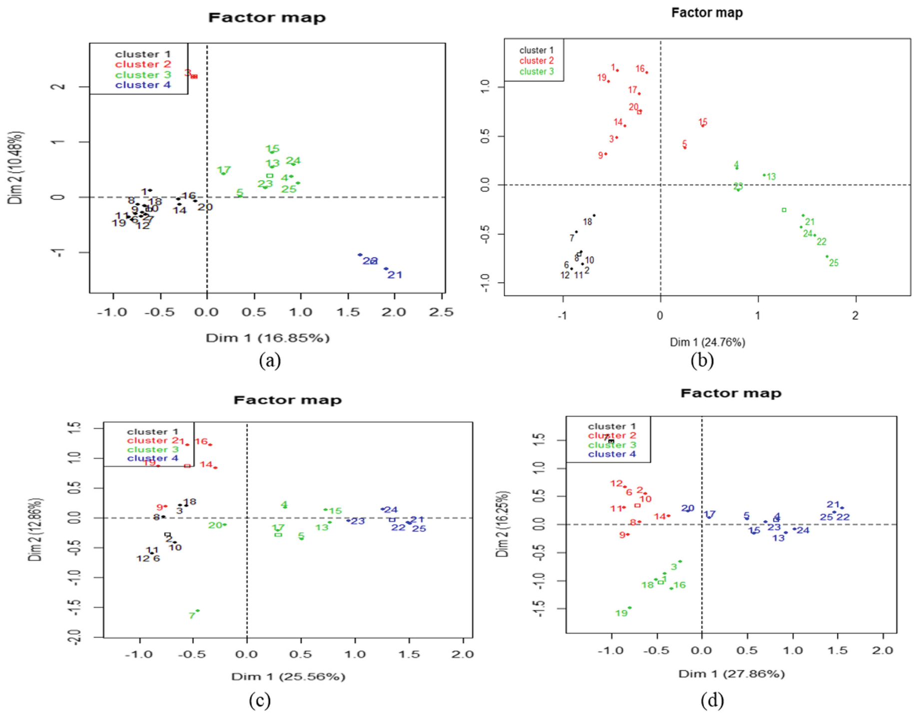


Fig. 5. Factor map for criterions (a) Planning; (b) Application; (c) Verification; (d) Improvement

Considering the results from "Planning" criteria (refer to Fig. 5a), we identified 4 clusters: Cluster 1, comprised of 56% of the companies analyzed, group 2 composed of 4% of the companies, cluster 3 represented by the 32% of the companies and cluster 4 made up of 8% of the companies analyzed. In this regard, cluster 1 is characterized by the presence of large companies, with more than 20 years old and constituted as companies by shares. In this cluster, companies with PREMIUM levels are located in the planning component, especially in the sub-criteria of strategic planning (SC1), the scope of the OHS system (SC3), OHS policy (SC4), objectives and OHS programs (SC5), participation and consultation (SC6), responsibility and authority in OHS (SC7), identification of risks in OHS (SC8), and leadership (SC9). Cluster 2 is comprised of a large company, between 11–20 years old, that presents an EXPERT level in the planning factor, in the OHS policy sub-factors (SC4), objectives and OHS programs (SC5), and participation and consultation (SC6). Cluster 3 is made up of companies of a limited nature, with a national scope in their operations. This group is at the EXPERT level in the subcriteria of leadership, strategic planning, and responsibility and authority in OHS and INITIAL level in the sub-factors objectives and OHS programs, OHS policy, and participation and consultation. Finally, cluster 4 is formed by small companies, with antiquity between 6 and 10 years and a BASIC level in the planning component, particularly in the sub-criteria related to the scope of the OHS system, stakeholders in OHS, strategic planning and responsibility and authority in OHS. In this sense, it is observed a good performance in the planning criterion, but it is necessary to establish strategies to improve the performance of the companies in cluster 3 and 4.

Taking into account the outcomes of the “Application” criterion (refer to Fig. 5b), it can be observed in 3 clusters. Cluster 1, made up of 32% of the companies analyzed, cluster 2 composed of 40% of the companies, and cluster 3 represented by 28% of the companies evaluated. Group 1 is comprised of large companies, with more than 20 years old and with operations not only nationally but also internationally. In this cluster, companies with PREMIUM levels are located in the application component, especially in the sub-criteria procedures and protocols (SC10), records and statistics (SC11), training in OHS (SC13), communication in OHS (SC14), operational controls (SC15), diagnosis of implementation OHS (SC16), and contingency plans (SC17). Cluster 2 is composed of medium-sized companies that present an EXPERT level in the application factor, especially in the sub-factors records and statistics (SC11), training in OHS (SC13), communication in OHS (SC14), operational Controls (SC15), diagnosis of OHS implementation (SC16), and contingency plans (SC17). On the other hand, cluster 3 is represented by small companies, with antiquity between 6 and 10 years and scope of operations at a national level. The companies in this cluster are at the INITIAL and BASIC levels, in the sub-criteria procedures and protocols (SC10), records and statistics (SC11), resources (SC12), training in OHS (SC13), communication in OHS (SC14), operational controls (SC15), diagnosis of implementation OHS (SC16), and contingency plans (SC17).

Another criterion is “verification” (refer to Fig. 5c). In this category, we identified 4 clusters: Cluster 1, made up of 32% of the companies analyzed, cluster 2 integrated by 20% of the companies, cluster 3 represented by 28% of the companies evaluated and the cluster 4 with 20% of the observations. Cluster 1 is integrated by large companies, which obtained a PREMIUM performance in the sub-criteria of management review (SC18), OHS indicators (SC19) and internal audits (SC20). In the cluster 2, companies with an EXPERT level were located in the sub-factors of management review (SC18), OHS indicators (SC19) and at the initial level in the sub-criterion of internal audits (SC20). For cluster 3, the companies obtained the INITIAL level in the sub-factor of internal audits (SC20) and the ADVANCED level in the OHS indicators sub-criterion (SC19). In cluster 4, most of the small companies, with antiquity between 6 and 10 years old, obtained BASIC and INITIAL levels in the subcriteria associated with the “verification” factor.

Based on the results of the “Improvement” category (refer to Fig. 5d), we observed 4 clusters: Cluster 1, made up of 4% of the companies analyzed, cluster 2 composed of 40% of the companies, cluster 3 represented by 20% of the companies evaluated and cluster 4 with 36% of the observations. Cluster 1 is made up of a large company, with more than 20 years old and with an international scope in its operations. However, in the “improvement” factor, it obtained BASIC level results in the subcriteria associated with the investigation of incidents (SC22), and nonconformities and corrective actions (SC23). Cluster 2 is represented by companies with more than 20 years of seniority and international presence. These companies obtained award levels in the subcriteria investigation of incidents (SC22), nonconformities and corrective actions (SC23) and to a lesser extent, in improvement actions (SC21). In cluster 3, companies with

EXPERT levels were located in the sub-factors investigation of incidents (SC22), nonconformities, and corrective actions (SC23). Group 4 is made up mostly of small companies, with antiquity between 6 and 10 years and national operations. These companies obtained ADVANCED performance levels in the sub-factor improvement actions (SC21) and an INITIAL level in the investigation of incidents (SC22), and nonconformities and corrective actions (SC23).

Finally, the chi-squared test was performed to analyze the independence of the variables or sub-criteria for each criterion or factor. The dependent or significant variables were those that obtained a p-value lower than the level of significance (p-value < 0.05). Table 4 shows the significative subcriteria in the evaluation of occupational health and safety performance. In this sense, the results obtained show that all the criteria and sub-criteria validated by the experts, taking into account the legal regulations, the ISO 45001 Standard and the pertinent literature, are significant in the evaluation of Occupational Health and Safety performance and the formation of business clusters. On the other hand, we identified other significative variables were also found in the survey for the MCA method, such as the age of the company, the legal nature of the company, the size of the company and the export orientation, which affect the level of Overall performance in OHS. These results allow us to conclude that the factors and sub-factors identified are relevant in the evaluation of occupational health and safety performance and that, through these criteria and sub-criteria, groups of companies can be identified and characterized to design multivariate strategies for the improvement in the management of health and safety in the land cargo transport sector.

Table 4. Rating scales Chi-squared test for independent analysis in software R 3.5.1.

Criterion (C)	Subcriteria (SC)	p-value
Planning (C1)	Strategic planning (SC1)	0.00000218
	Stakeholders in OHS (SC2)	0.00131
	Scope of the OHS system (SC3)	0.0000102
	OHS Policy (SC4)	0.0000000282
	Objectives and OHS programs (SC5)	0.0000000282
	Participation and consultation (SC6)	0.000000124
	Responsibility and authority in OHS (SC7)	0.0000214
	Identification of risks in OHS (SC8)	0.00831
	Leadership (SC9)	0.00139
Application (C2)	Procedures and protocols (SC10)	0.00109
	Records and statistics (SC11)	0.0000461
	Resources (SC12)	0.00203
	Training in OHS (SC13)	0.000000452
	Communication in OHS (SC14)	0.00000694
	Operational Controls (SC15)	0.00000000470
	Diagnosis of implementation OHS (SC16)	0.000935
	Contingency plans (SC17)	0.00000328

(*continued*)

Table 4. (*continued*)

Criterion (C)	Subcriteria (SC)	p-value
Verification (C3)	Management review (SC18)	0.00000513
	Indicators OHS (SC19)	0.0000000153
	Internal audits (SC20)	0.000446
Improvement (C4)	Improvement actions (SC21)	0.00219
	Investigation of incidents (SC22)	0.00000000127
	Nonconformities and corrective actions (SC23)	0.000000110

4.4 Calculating the Relative Weights of Criteria and Sub-criteria Using FAHP

Via the FAHP method, the local and global contributions of sub-criteria were determined to take into account importance, and uncertainty environments. To do this, the fuzzy judgment matrixes were initially calculated based on the pairwise comparisons performed by the selected experts. An example of this matrix is shown in Table 5. An illustration of a fuzzy reciprocal comparison matrix is presented in Table 6 where the judgments derived from the questionnaire were aggregated by applying Eqs. 1–3. The geometric means of fuzzy comparisons were then computed for each criterion/sub-criterion (refer to Table 6). The normalized priorities of criteria and sub-criteria were estimated after defuzzification by use of Eq. 4 and Eqs. 5–7 (refer to Table 7). Table 8 depicts the local (LW) priorities of sub-criteria as well as the global weights (GW) of all the decision elements of the model; a result of multiplying their local priority by the GW of its respective parent criterion.

Table 5. Fuzzy reciprocal comparison matrix for criteria

	C1	C2	C3	C4
C1	[1, 1, 1]	[1.64, 2.19, 2.69]	[1.64, 2.19, 2.69]	[1.64, 2.19, 2.69]
C2	[0.30, 0.39, 0.55]	[1, 1, 1]	[1.35, 1.60, 1.81]	[0.47, 0.58, 0.74]
C3	[0.45, 0.53, 0.67]	[0.55, 0.62, 0.74]	[1, 1, 1]	[0.41, 0.53, 0.74]
C4	[0.37, 0.46, 0.61]	[1.64, 2.02, 2.34]	[1.81, 2.56, 3.28]	[1, 1, 1]

Table 6. Geometric means of fuzzy comparisons for criteria

Criterion	C1	C2	C3	C4
Geometric mean of fuzzy comparisons	[1.64, 2.19, 2.69]	[0.54, 0.68, 0.88]	[0.66, 0.82, 1.05]	[0.78, 0.96, 1.19]

Table 7. Normalized fuzzy priorities for criteria

Fuzzy weight				Non-fuzzy weight	Normalized weight
C1	9.54	10.19	9.74	9.82	0,463
C2	3.15	3.15	3.17	3.16	0,149
C3	3.82	3.82	3.80	3.81	0,180
C4	4.54	4.46	4.32	4.44	0,209
Total				21.23	

Table 8. LW and GW of criteria and sub-criteria

Cluster	GW	LW
Planning (C1)	**0.463**	
Strategic management (SC1)	0,068	0,148
Stakeholders (SC2)	0,021	0,046
Scope of OHS (SC3)	0,018	0,040
Policy of OHS (SC4)	0,068	0,148
Objective of OHS (SC5)	0,064	0,138
Participation of workers (SC6)	0,029	0,064
Responsibilities and authority (SC7)	0,032	0,070
Risk management (SC8)	0,040	0,087
Leadership (SC9)	0,121	0,261
Application (C2)	**0.149**	
Procedures and protocols (SC10)	0,014	0,097
Records and statistics in OHS (SC11)	0,013	0,088
Resources for OHS (SC12)	0,024	0,164
Education and Training (SC13)	0,014	0,096
Communication in OHS (SC14)	0,009	0,061
Operational Controls (SC15)	0,028	0,189
Diagnosis in OHS (SC16)	0,029	0,197
Contingency plans (SC17)	0,016	0,109
Verification (C3)	**0.180**	
Management review (SC18)	0,040	0,221
Evaluation of OHS (SC19)	0,067	0,375
Audit od OHS (SC20)	0,073	0,404
Improvement (C4)	**0.209**	
Improvement plans (SC21)	0,128	0,613
Incident investigation (SC22)	0,052	0,247
Nonconformities and corrective plans (SC23)	0,029	0,140

Considering the FAHP results, first, the global weights of criteria were graphed in Fig. 6. By analyzing this bar diagram, it can be said that "Planning" is the most relevant criterion (NF = 46.3%) when assessing the overall performance in occupational health and safety. This criterion presents a difference of more than 20% compared to the other factors of the model. These results indicate that planning is an essential aspect for the success in the implementation of Occupational health and safety management systems so that companies in the sector must generate strategies and actions aimed at realizing effective planning processes in OHS. "Improvement" was also identified as an important factor in the evaluation (NF = 20.9%). However, there is a big difference (6%) between this factor and the last one in the "Implementation" ranking. These results demonstrate that the overall performance in occupational health and safety is the result of different strengths that underpin the companies in the prevention of accidents and occupational diseases, taking into account the regulations and standards in OHS, contributing in the corporate competitive plans and the decision making process in the land cargo transportation sector. Therefore, it is essential to design multi-criteria strategies aimed at continuous improvement in occupational health and safety taking into account different aspects of the P-D-C-A (Plan-Do-Check-Act) cycle (planning, application, verification, improvement)

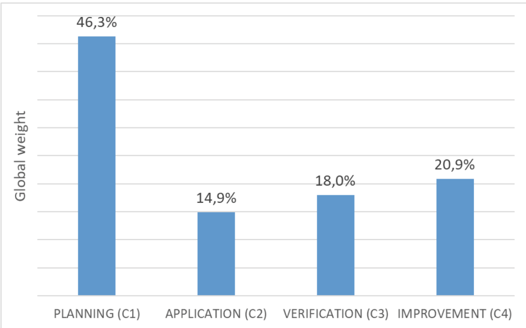


Fig. 6. Global weights of criteria when assessing the overall performance in occupational health and safety in companies of land cargo transportation

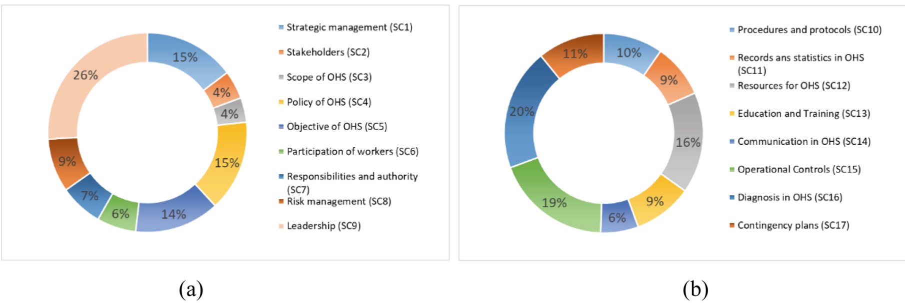
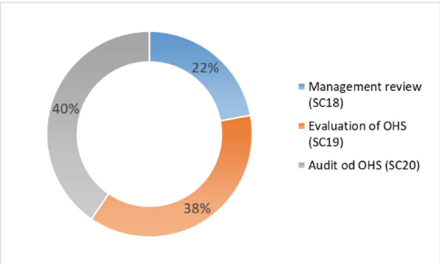
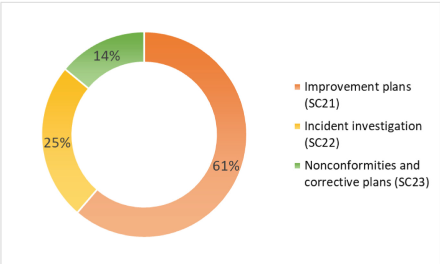


Fig. 7. Local contributions for factors (a) Planning (b) Application

Considering the results from "Planning" cluster (refer to Fig. 7a), "Leadership" was selected as the most important sub-criterion (26%). Other subfactors such as "Strategic management" (15%), Policy of OHS (15%) and "Objective of OHS" (14%) were identified as important sub-criteria in the planning cluster. This result means that the aforementioned sub-criteria are equally relevant in the overall performance evaluation in the planning cluster because these elements are conditions of compliance in mandatory national regulations and international standards in occupational health and safety that must be fulfilled by the companies in the land cargo transportation sector. In the "Application" category (refer to Fig. 7b), "Diagnosis in OHS" was chosen as the most relevant sub-factor (20%). Although there is a slight difference between this sub-category and other sub-factors as "Operational controls" (19%) and "Re-sources for OHS." These factors being relevant when evaluating the performance in terms of application, since these sub-criteria are requirements of national regulations in OHS and the standard ISO 45001, with the objective of identifying the initial conditions to implement the standard, establish the work plans, and ensuring physical, technological and infrastructure resources for occupational health and safety. Therefore, these variables must be controlled and monitored to generate a culture of prevention in companies and obtain good outcomes in performance evaluation.



(a)



(b)

Fig. 8. Local contributions for factors (a) Verification (b) Improvement

Taking into account the results of the "Verification" criterion (refer to Fig. 8a), it can be observed that "Audit of OHS" (40%) represents the highest preference even though there are no significant differences between the decision elements of this cluster for example with the sub-factor "Evaluation" (38%). In this regard, both the legal regulation and the standard ISO 45001 define the audit as a systematic process of evaluation of evidence to compare against the criteria and objectives of the system, in order to establish the actions for continuous improvement. This means that the audit involves in itself an evaluation process and serves as a basis for management review, which is why it is a relevant sub-criterion in the evaluation. Finally, in the "Improvement" cluster, (refer to Fig. 8b), "Improvement plans" contribute with 61% of the total criterion weight. In this sense, this sub-criteria allows the development of strategies to promote the continuous improvement in occupational health and safety, which also involves the analysis of accidents and the identification of nonconformities, but with a focus on prevention and development.

On the other hand, consistency values were estimated (refer to Table 9) to verify the reliability of the judgments provided by the participants. The results revealed that all matrices yielded good consistency values (CR $\leq$ 0.1). Consequently, considering the above-mentioned findings, the data-collection procedure can be regarded as robust and the outputs derived from the decision-making process can be hence concluded as highly reliable regarding the calculated priorities of criteria and sub-criteria. Therefore, the data-gathering process can be considered satisfactory and subsequently, the decision-making process with highly reliable results.

Table 9. Consistency values for FAHP matrices

Cluster	Consistency ratio (CR)
Criteria	0.015
Planning	0.092
Application	0.088
Verification	0.086
Improvement	0.031

Finally, with the calculation of the weights of the criteria and sub-criteria, the scores of the general evaluation of performance in OHS of each of the participating companies were obtained, with which the ranking of the companies was obtained. of these results (refer to Fig. 9). In the top 5 are 4 large companies and a medium-sized company, these companies have more than 20 years of antiquity, and their operations are developed both nationally and internationally. On the other hand, small companies were located in the last places of the ranking, so it is necessary to design and implement plans for improvement in their overall performance. Table 10 shows an example with the results of one of the companies analyzed and the calculation of the GAP, at a general level and by the factor, which serves as the basis for the approach to improvement strategies.

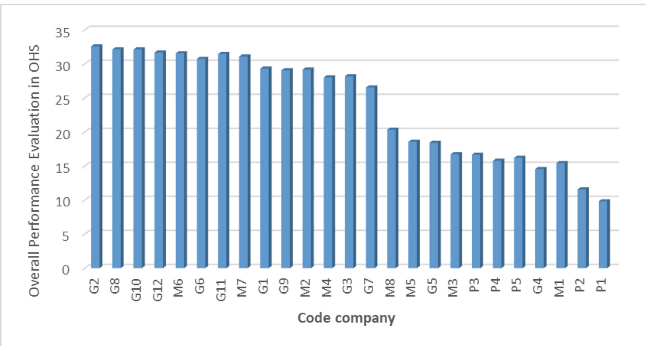


Fig. 9. Ranking of classification companies when assessing the overall performance in occupational health and safety of land cargo transportation sector

Table 10. Example of results overall performance evaluation in OHS

Code company	C1	C2	C3	C4	Total score
G1	20	5	2	3	29
Score max	21	25	13	8	67
% of compliance	95,2%	20.0%	15.3%	37.5%	43,8%
GAP	4,8%	80.0%	84.7%	62.5%	56,2%

5 Conclusions and Future Work

The land cargo transportation presents a high rate of accidents due to the risks inherent to the sector (psychosocial factors, mechanical and physical hazards, risks of security, among others) which hurt the welfare of workers, on operational costs, on logistics indicators, on the compliance with legal regulations and customer satisfaction. In this sense, it is necessary to develop integrated models cuali-cuantitative that provide information on occupational health and safety performance in the land cargo transportation to detect critical points, classify companies considering their levels of management and, subsequently, design strategies of improvement.

This research enriches the scientific literature and contributes to the evidence base related to the use of integrated approaches based on Multivariate Correspondence Analysis (MCA) and Fuzzy AHP for evaluation of performance in occupational health and safety in the companies of land cargo transportation sector with the aim of reduce the rates of accidents and incidents, losses for companies, increasing the competitiveness of the industry. In this regard, as future work, the integrated methodology will be extended in other economic sectors. In addition, we propose a comparison of the approach proposed in this project with different hybrid methods as DEMATEL, TOPSIS, and VIKOR to validate and improve the performance of the method.

The results showed that the factors associated to planning, application, verification, and improvement are dependent factors in the overall evaluation in occupational health and safety, and different clusters were identified considering the factors of evaluation. In addition, it was evidenced that the size, seniority and international scope of the companies are related to the level of performance in occupational health and safety. The outcomes of the FAHP showed that the factors with the most significant weight in the evaluation of occupational health and safety performance are Planning (46.3%) and Improvement (20.9%). The criterions associated to Verification (10.8%) and Application (14.9%) present few differences regarding the weights in the evaluation, which evidences the preventive nature of this proposed integrated model for the assessment of the performance in occupational health and safety in the companies of land cargo transportation.

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