SPANISH VERSION...

Iberoamerican analysis and classification of labor accidents in the civil construction industry

Análisis y clasificación iberoamericana de la accidentalidad laboral en la industria de la construcción civil

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Abstract

Millions of accidents and thousands of deaths resulting from work activity occur every year and 30% of this comes from civil construction. As to this sector is one of the engines of the Ibero-American economies, it becomes important to identify the behavior of the occupational injuries in the region. For this reason, the main objective of this article is the development of an analysis of Ibero-American occupational accidents in the construction sector, based on the results obtained from official statistical sources for the period 2013-2017. This article was carried out through quantitative surveys, statistical observations, determination of correlations and use of the multicriteria methods AHP and TOPSIS. The main results of this investigation were the characterization of the problem, an Ibero-American ranking of accidents and an analysis of the basic aspects required to the employers of each country involved. It was also possible to identify that in the period of analysis the region had an improvement in the fight against this problem, as there was a successive reduction in the accident figures over time.

Keywords: *Occupational accident; civil construction; Ibero-America; multicriteria methods; ranking*

Resumen

Anualmente acontecen millones de accidentes y miles de fallecimientos derivados de la actividad laboral, siendo el 30% de estos siniestros aportados por la construcción civil. Conociendo que este sector es uno de los motores de las economías iberoamericanas, se torna relevante identificar el comportamiento de la siniestralidad laboral de dicha industria en la región. Por tal motivo, este artículo presenta como objetivo principal el desarrollo de un análisis sobre la accidentalidad laboral iberoamericana en el sector construcción, con base en resultados obtenidos de fuentes estadísticas oficiales para el periodo 2013-2017. El estudio en mención se llevó a cabo mediante investigaciones cuantitativas, observaciones estadísticas, determinación de correlaciones y uso de los métodos multicriterio AHP y TOPSIS. De esta investigación se obtuvieron como resultados principales: la caracterización de la accidentalidad, un ranking Iberoamericano de siniestralidad y el análisis de aspectos básicos exigidos a empleadores de cada país involucrado. Asimismo, se consiguió identificar que en el periodo de análisis la región tuvo una mejoría en la lucha en contra de esta problemática, ya que se registró una reducción sucesiva en las cifras de accidentalidad a través del tiempo.

Palabras clave: Accidentalidad laboral; construcción civil; Iberoamérica; métodos multicriterio; ranking

1. Introduction

According to the International Labor Organization (OIT, 2015), it was estimated that approximately one worker dies every 90 seconds and 895 suffer accidents as a consequence of their work. This represents 350,000 deaths and 313 million accidents annually worldwide. Around 30% of these accidents occurred in the construction sector.

Similarly, taking into account the information from this organization, it is known that personnel working in the construction industry are 3 to 4 times more likely to die from occupational accidents than those working in other industries. This is mainly due to the extreme working conditions to which workers are exposed (Solís, 2017). Given the above, it is clear that the issue of occupational injuries in the civil construction industry generates significant human losses, affecting society and the economy. Therefore, it is a serious global problem that deserves to be studied (Zhang, 2013).

It is important to mention that construction is one of the industries with the greatest influence on the progress and financial growth of nations around the world because of its strong influence on other sectors that are predominant in the economy, mainly as a result of the close relationship between infrastructure and development (Pérez-Foguet et al., 2007); (Martínez-Aires et al., 2015). Based on this financial influence, it is noteworthy that construction provides opportunities for low-skilled or unskilled workers, helping to reduce unemployment with low investment by eliminating training costs (Galindo and Sosvilla, 2012).

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However, the positive factors mentioned above are contradictory since they also lead to labor informality and accidents (Del Águila, 2015), thus affecting the productivity, quality, and reputation of companies (Enshassi et al., 2009). This produces an additional public health problem and, at the same time, a loss of public and private funds. In the case of Europe, only considering working hours lost due to accidents at work, 2.6% or more of the gross domestic product (GDP) is lost annually (Oliveira et al., 2012). Globally, according to (Takala et al., 2014), the economic costs to countries from occupational injuries including work-related diseases range from 1.6% to 6.0% of total national GDP.

It is noteworthy that one of the key points for success in the construction industry is occupational safety since investing in this parameter reduces costs, increases production efficiency and, most importantly, preserves life. (González et al., 2016).

For the development of this study, some of the most important countries in Ibero-America[1] were chosen, including Argentina, Brazil, Chile, Colombia, Spain, Mexico, Peru, Portugal, and Uruguay. The focus of this study was the safety and health at work (SHAW), having as main objectives the analysis of the figures of accidents in the Ibero-American civil construction industry for the period 2013-2017 and the creation of annual Ibero-American rankings of occupational accidents in the sector through the application of the Analytic Hierarchy Process (AHP) and Technique for order preference by similarity to ideal solution (TOPSIS) methods. For the creation of the classifications, the accident rate was related to other important figures, such as the GDP and the human development index (HDI).

This study is justified by three fundamental aspects: (i) Although the topic is well identified in the literature, effective monitoring of results is necessary to identify trends and make the necessary decisions for their prevention, considering that it evaluates the statistics that demonstrate the risk that still exists in Ibero-American construction companies; (ii) it addresses an issue that, due to the significant financial and social costs, requires sound management of construction works, so it is necessary to establish a risk management model consistent with its importance; (iii) it provides essential knowledge to manage work-related risks, which is extremely useful to develop strategies to mitigate accidents that generate risk in construction.

It is important to emphasize that the relevance of this study lies in the fact that the results obtained can help the health authorities of the countries involved to have a clearer vision of the behavior in the fight against occupational accidents, providing a basis for the orientation of future preventive activities and SHAW policies, specifically for the construction sector. Also, this study will help to fill a gap that exists in the region regarding the use of TOPSIS and AHP multi-criteria models together, to address the existing problems in construction.

2. Methodology

Because of its characteristics, this study is considered as a quantitative, correlative and descriptive non-experimental research, in which the problem of occupational injuries in the civil construction industry of Ibero-America was described. The research was developed by observing and relating different factors without manipulating the natural conditions or the variables analyzed, aiming to observe the performance of the countries in terms of accident rates and mortality. This can also be classified as longitudinal research since data were analyzed over time for annual periods between the years 2013 and 2017 (Hernández et al., 2010).

This study was carried out with secondary data (Malhotra, 2008). The selection of the sample was projected and then defined by the availability of the data, which were mostly collected from the national institutes of statistics. Taking this into account, it is important to point out that a forced selection of the sample was carried out since only 9 of the 22 countries that were considered to be included in the research showed relevant data for the development of the study. From the beginning, it can be seen that many of the Ibero-American nations show little concern for collecting and disseminating the accident figures, despite the knowledge that we have today about the socio-economic impact that the problem represents. The sample was made up of 9 countries, 7 from Latin America and 2 from the Iberian Peninsula. These data are considered to be significant since they represent an average of 80.0% of the population and 85.3% of the GDP (current prices) of all Ibero-America for the period under analysis. (Table 1) shows the data sources used.

In addition, for the development of the study, a database was initially created to collect the information and observation of outliers was carried out, to later conduct an analysis using basic descriptive statistics with the intention of identifying behaviors, trends and generalities in the variables associated with accidents and deaths.

[1] According to the Ibero-American General Secretariat (2018), the support organization associated with the Ibero-American summits of nations, Ibero-America is made up of 22 countries, 19 from Latin America and 3 from the Iberian Peninsula. The countries are: Andorra, Argentina, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Chile, Dominican Republic, Ecuador, El Salvador, Spain, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Portugal, Uruguay and Venezuela.

Then, the most influential variables linked to the problem of occupational injuries were evaluated, with the concept of normality, to choose the most appropriate method to find mathematical correlations between them. The variables used in the study were: contribution percentage of construction to the GDP (from the Spanish Porcentaje de Aporte de la Construcción al PIB, APIB), number of companies and employers in the construction sector (from the Spanish cantidad de empresas y empleadores en el sector construcción, CEC), number of workers in construction (from the Spanish cantidad de trabajadores en la construcción, CTC), number of occupational accidents in construction (from the Spanish número de accidentes de trabajo en la construcción, CAT), rate of occupational accidents per 100. 000 workers in construction (from the Spanish Tasa de Accidentes de Trabajo, TAT), number of deaths in occupational accidents in construction (from the Spanish Número de Muertes en Accidentes de Trabajo en la Construcción, CMT), rate of deaths per 100,000 workers in construction (from the Spanish Tasa de Muertes por Cada 100.000 Trabajadores en la Construcción, TMT), percentage of occupational accidents in construction (from the Spanish Porcentaje de Accidentes de Trabajo, PAT) and percentage of deaths of workers in construction (from the Spanish Porcentaje de Muertes de Trabajadores, PMT).

The labor force (from the Spanish, Población Económicamente Activa, PEA) and HDI variables were also included. For the determination of normality, the Shapiro-Wilk test was specifically used. Pearson's and Spearman's methods were used for correlations.

Table 1. Sources of statistical data of the research.[2]

COUNTRY	SOURCE
ARGENTINA	Superintendencia de Riesgos del Trabajo (SRT)
BRASIL	Previdencia social - Instituto Brasileño de Geografía y Estadística (IBGE) - Cámara Brasileña de la Industria de la Construcción (CBIC)
CHILE	Superintendencia de seguridad social
COLOMBIA	Federación de Aseguradores Colombianos (FASECOLDA) - Departamento Administrativo Nacional de Estadística (DANE)
ESPAÑA	Instituto Nacional de Estadística España (INE) - Ministerio de Trabajo, Migraciones y Seguridad Social
MÉXICO	Instituto Mexicano de Seguro Social
PERÚ	Ministerio de Trabajo y de Promoción del Empleo - Instituto Nacional de Estadística e Informática (INEI)
PORTUGAL	Autoridad para las Condiciones de Trabajo (ACT) - Gabinete de Estrategia y Planeamiento (GEP) - Base de Datos Portugal Contemporáneo (PORDATA)
URUGUAY	Instituto Nacional de Estadística Uruguay (INE) - Ministerio de Trabajo y Seguridad Social - Centro de Estudios Económicos de la Industria de la Construcción (CEEIC) - Banco de Seguros del Estado (BSE) - Banco de Previsión Social (BPS)

After the previous stage, bearing in mind that one of the main objectives of the study is to create Ibero-American accident classifications, the multi-criteria decision methods TOPSIS and AHP were implemented. TOPSIS was implemented to create the classification and AHP was implemented to determine the percentage weights that would be assigned to each of the implicit criteria in the TOPSIS method. The mathematical calculations associated with this study were developed in SPSS 15.0 and Excel 2016 software.

3. Results and discussions

(Table 2) shows an extract from the research database, where some of the most relevant variables used in the mathematical analyses described in the methodology are listed. Their results are included in this section.

[2]The labor force and HDI figures for all countries were obtained from the databases of the World Bank and United Nations Development Program (UNDP), respectively. With regard to the data on the contribution of construction to the GDP, the figures were obtained from the Economic Commission for Latin America and the Caribbean (from the Spanish Comisión Económica para América Latina y el Caribe, CEPAL), INE Portugal and INE Spain.

Table 2. *Database extract*

COUN TRY	YEARS	PEA	APIB	HDI	CEC	CTC	CAT	CMT	TAT	TMT
Argentina	2013	19.151.572	4,88	0,82	22.504	435.475	58.296	119	13.387	27,33
Argentina	2014	19,207,364	4.64	0,82	22,388	431,017	56,283	105	13,058	24.36
Argentina	2015	19,486,951	4.57	0.822	22,520	462,161	60,236	104	13,034	22.50
Argentina	2016	19,704,082	3.85	0.822	22,081	419,989	49,344	92	11,749	21.91
Argentina	2017	19,901,885	4.12	0.825	22,215	449,630	51,816	97	11,524	21.57
Brasil	2013	99,541,859	5.45	0.748	223,773	3,094,153	61,608	459	1,991	14.83
Brasil	2014	100,603,554	5.31	0.752	237,919	3,019,427	59,117	446	1,958	14.77
Brasil	2015	102,301,658	4.94	0.757	233,343	2,585,168	44,809	335	1,733	12.96
Brasil	2016	103,214,044	4.39	0.758	215,039	2,122,335	36,728	284	1,731	13.38
Brasil	2017	104,278,222	4.11	0.759	200,716	1,961,791	29,711	227	1,514	11.57
Chile	2013	8,503,214	6.52	0.828	14,458	604,940	35,933	99	5,940	16.37
Chile	2014	8,640,594	6.33	0.833	17,447	583,017	32,422	68	5,561	11.66
Chile	2015	8,755,232	6.58	0.84	21,223	580,124	32,697	67	5,636	11.55
Chile	2016	8,841,540	6.8	0.842	22,052	593,830	34,260	74	5,769	12.46
Chile	2017	8,963,428	6.52	0.843	23,432	590,837	30,741	54	5,203	9.14
Colombia	2013	25,001,105	6.73	0.735	74,622	918,055	96,471	150	10,508	16.34
Colombia	2014	25,321,884	7.28	0.738	64,850	961,990	111,271	119	11,567	12.37
Colombia	2015	25,773,738	7.21	0.742	68,931	1,040,344	117,341	120	11,279	11.53
Colombia	2016	26,020,330	7.52	0.747	73,552	1,034,395	105,691	126	10,218	12.18
Colombia	2017	26,421,385	6.82	0.747	78,571	961,739	88,102	92	9,161	9.57
España	2013	23,376,875	5.26	0.875	425,593	1,029,475	44,319	62	4,305	6.02
España	2014	23,144,274	5.12	0.88	408,089	993,500	45,366	73	4,566	7.35
España	2015	23,057,270	5.09	0.885	405,849	1,073,650	51,548	78	4,801	7.26
España	2016	23,016,544	5.1	0.889	406,682	1,073,850	56,446	64	5,256	5.96
España	2017	22,966,950	6.12	0.891	402,923	1,128,325	64,719	80	5,736	7.09
México	2013	54,293,599	7.44	0.756	98,680	1,211,501	43,770	193	3,613	15.93
México	2014	54,835,995	7.34	0.761	103,047	1,368,318	43,323	193	3,166	14.10
México	2015	56,018,784	7.38	0.767	108,580	1,416,283	48,833	220	3,448	15.53
México	2016	56,990,890	7.41	0.772	115,179	1,520,838	46,118	192	3,032	12.62
México	2017	58,072,901	7.45	0.774	121,480	1,563,708	49,260	162	3,150	10.36
Perú	2013	17,052,108	6.89	0.736	48,745	975,696	2,776	18	285	1.84
Perú	2014	17,169,769	7.12	0.746	49,747	1,014,384	2,021	18	199	1.77
Perú	2015	17,209,815	6.95	0.745	53,364	1,043,596	3,231	31	310	2.97
Perú	2016	17,532,996	6.59	0.748	55,807	997,338	2,413	26	242	2.61
Perú	2017	17,902,590	6.98	0.75	63,428	957,515	1,770	24	185	2.51
Portugal	2013	5,297,389	3.96	0.837	81,335	307.907	26,435	42	8,585	13.64
Portugal	2014	5,241,883	3.63	0.839	77,844	294.458	27,309	41	9,274	13.92
Portugal	2015	5,218,238	3.54	0.842	77,906	297.344	28,587	44	9,614	14.80
Portugal	2016	5,207,267	3.38	0.845	78,866	301.862	25,302	42	8,382	13.91
Portugal	2017	5,173,734	3.5	0.847	75,864	302.494	26,117	35	8,634	11.57
Uruguay	2013	1,728,421	9.69	0.797	6,159	276.048	6,985	10	2,530	3.62
Uruguay	2014	1,752,284	9.76	0.801	6,367	275.734	6,218	10	2,255	3.63
Uruguay	2015	1,751,444	9.55	0.8	6,433	276.484	4,754	5	1,719	1.81
Uruguay	2016	1,754,212	9.62	0.802	6,466	257.547	3,853	1	1,496	0.39
Uruguay	2017	1,769,073	9.4	0.804	6,926	264.504	3,221	4	1,218	1.51

3.1 Accident rate analysis

To begin with this analysis, it is important to define what an occupational accident is. An occupational accident is any sudden event occurring in the workplace, or resulting from work, where the worker contracts a physical injury that requires medical attention and results in temporary or permanent disability or death (Acevedo and Yánez, 2016). From this definition and remembering that the problem of occupational injuries generates various consequences in both social and economic areas, where those most affected are the workers and their families, it becomes crucial to analyze the behavior of the accident figures in civil construction.

It is important to mention that the data on occupational accidents and deaths used in this study include accidents in the workplace and also in itinere[3] since the figures obtained from official agencies in most countries do not discriminate between the types of accidents.

3.1.1 Number and percentage of accidents of workers in civil construction

Regarding the number of accidents (CAT) occurring year after year in the countries under study, the following behaviors were observed in the figures: a decreasing trend in Brazil and Uruguay and an increasing trend in Spain and Mexico. In the cases of Colombia, Chile, Argentina, Peru and Portugal, there was no defined trend because they showed fluctuating values that increased and decreased without a defined pattern in the period under evaluation (Table 2). In addition to this data set, Colombia, Argentina and Spain have the highest number of accidents (CAT), while Uruguay and Peru have the lowest values. (Figure 1) shows the total percentage of accidents contributed by country throughout the period of study from 2013 to 2017 (5 years). During this period, the evaluated countries recorded a total of 1,857,571 occupational accidents in the construction sector.

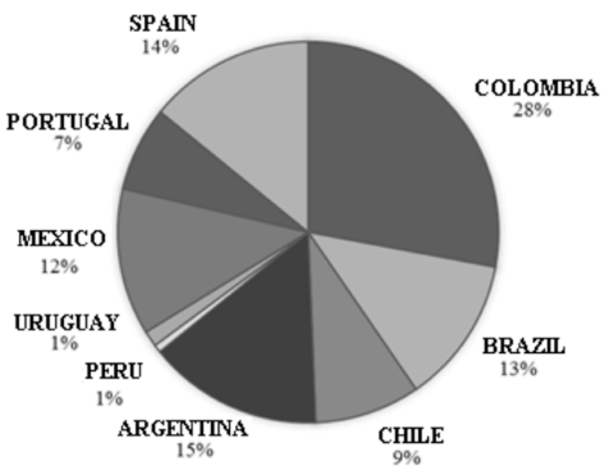

Figure 1. *Percentage of occupational accidents in the construction sector reported by country for the entire period 2013-2017.*

For the period 2013-2017, the percentage of occupational accidents occurred based on the total number of workers in the construction industry in each country (PAT) reached a regional average of 5.52%, representing 5,520 accidents per 100,000 workers. In addition, there was a general decreasing trend in this figure, which is a good indicator. It was also noted that Argentina, Colombia and Portugal have the highest accident percentages and that Peru, Uruguay and Brazil have the lowest values (Figure 2).

[3] In itinere occupational accidents are defined as accidents occurring on the way to or from the workplace (Almanzor y Martín, 2013).

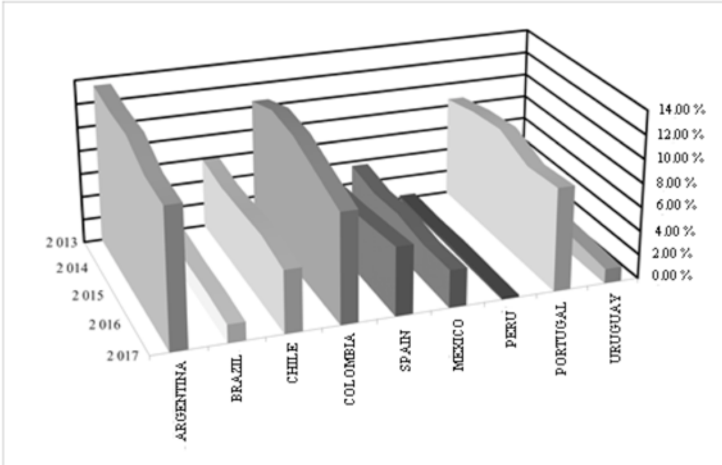

Figure 2. *Percentages of occupational accidents based on the total number of workers in the construction industry of each country (PAT) in the period 2013-2017.*

Finally, it is emphasized that the behavior of the countries, regarding the quantity and percentage of occupational accidents in construction, differs, mainly because the quantity of accidents is an independent variable and the percentage of accidents depends inversely on the number of workers which in turn is strongly correlated with the labor force (PEA) of each country.

3.1.2 Number and percentage of deaths of workers in civil construction

The number of deaths (CMT) is a variable of great importance since it exposes in figures the most serious consequence of occupational accidents. By analyzing CMT in this study, it was possible to observe a marked decrease in the number of fatal accidents in Brazil, maybe in part due to the decrease in the workforce of the sector in the years under study. For Colombia, Chile, Argentina, and Uruguay there was a general decreasing trend in this figure, although Colombia and Chile showed a slight increase in this figure from 2015 to 2016 and Argentina and Uruguay from 2016 to 2017. In the case of Portugal, there was a stability trend, with a slight decrease from 2016 to 2017. In the same way, in Mexico, these values remained constant in 2013 and 2014. In 2015, they had a significant increase, and in 2016 and 2017, they showed slight decreases. Finally, it is worth noting that the most unfavorable trends were observed in Peru and Spain, which showed a slightly increasing trend. This is particularly true for Spain. In addition, Brazil, Mexico and Colombia were the leading countries in terms of the number of deaths, while Peru and Uruguay were the countries with the lowest number of deaths (Table 2). (Figure 3) shows the total percentage of deaths reported by country over the entire period under study from 2013 to 2017 (5 years). During this period, a total of 4,905 deaths from occupational accidents in the construction sector were recorded in the countries under study.

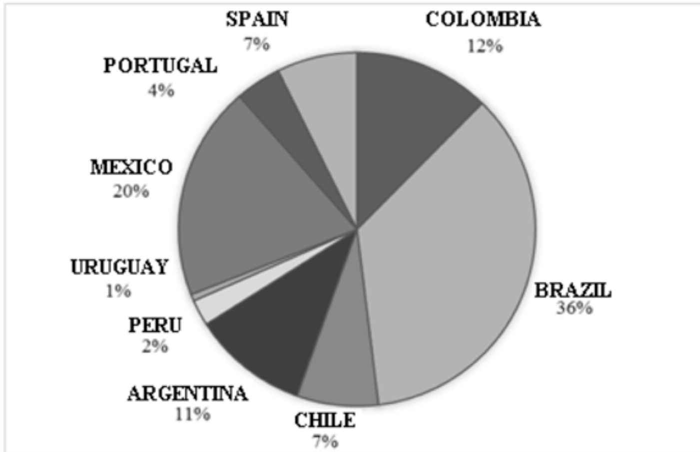

Figure 3. *Percentage of deaths in occupational accidents in the construction sector reported per country for the entire period 2013-2017.*

Regarding the percentage of deaths in occupational accidents based on the total number of construction workers in each country (PMT), there was an average in the evaluated countries in the period 2013-2017 of 0.01114%, a quite low figure, which indicates an excellent behavior, showing in a certain way an advance in SHAW by all the countries. Such a percentage represents approximately 11 deaths per 100,000 workers. For this data set, a decreasing trend was observed. However, Argentina, Mexico, Brazil and Portugal have the highest percentage of deaths, while Peru and Uruguay again show the lowest values, which makes them the two countries with the best behavior according to the figures analyzed so far (Figure 4).

After reviewing the analyses of accident rates and mortality, it is important to mention that, in the countries under study, especially those in Latin America, it is very difficult to record 100% of the accidents and deaths, since these data are directly related to the accident reporting systems of each country, which sometimes involve numerous paperwork, thus impeding the recording of accidents (Carlos, 2009). Also, it is well known that many of the accidents in the construction industry are left in the shadows because of the evident lack of transparency, especially in low-level positions. Given the above, it should be noted that the conditions of the study could be affected, resulting in some inaccuracy in the estimates.

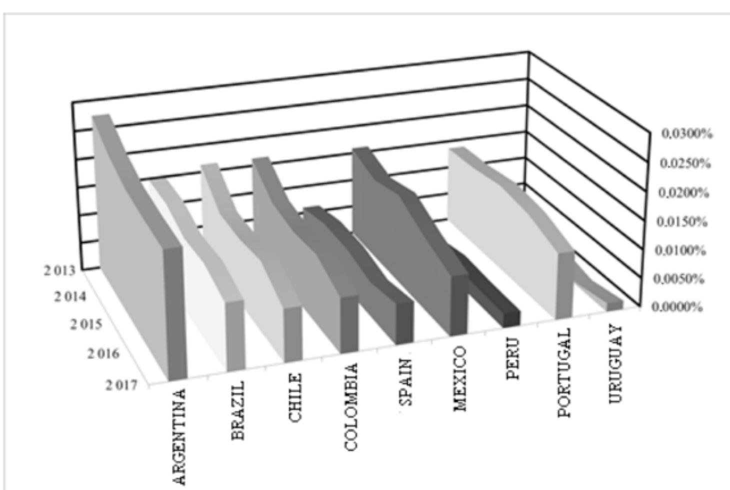

Figure 4. *Percentage of deaths in occupational accidents based on the total number of workers in the construction industry for each country (PMT) in the period 2013-2017.*

3.2 Correlations between variables

Establishing correlations between two or more variables is used to determine whether a mathematical association exists in their behavior and to know to what extent this interaction occurs (Rojas, 2007). Usually, two well-known methods are used. On the one hand, the Pearson's method specifically studies the linear correlations, for those quantitative variables that comply with the condition of normality and continuity (Filho and Júnior, 2009). On the other hand, the Spearman's method studies linear and non-linear correlations, between any type of quantitative variable, without considering special mathematical conditions, being a less restrictive method in its application (Restrepo and González, 2007).

Specifically, this study uses the Pearson correlation when the two variables to be associated were set as normal. On the contrary, where only one or none of the variables to be correlated were set as normal, the Spearman correlation was used. In order to detect possible non-linear correlations between the variables that showed normality, the Spearman's method was also applied to them. Given the above, first, the normality of the variables mentioned in the methodology was determined through the Shapiro-Wilk test. This method was used because the samples had less than 30 observations (Lopes et al., 2013). More precisely, 5 normality analyses per variable were carried out, one for each year under study. For this test, a 95% confidence interval for the mean was considered and only the variables that met this condition in all years under study were assumed to be normal.

In this sense, the APIB, the HDI, the percentage of accidents (PAT) and the percentage of deaths due to occupational accidents (PMT) were established as normal variables. Therefore, the Pearson's method was initially used to determine correlations between them. Based on (Table 3), values in the ranges -1.0 to -0.40 and 0.40 to 1.0 were considered to be relevant correlations. (Table 4) shows the results of the significant correlations found by this method, where a strong and direct linear correlation between the percentage of injured workers (PAT) and the percentage of worker deaths (PMT) is clearly observed, indicating that these two variables increase together, but in different proportions. A moderate and inverse correlation between the APIB and the PAT and PMT accident variables was also noted, revealing that when the first variable increases, the other two decrease but at a slower speed or vice versa.

***Table 3.** Coefficient Interpretation*

Value of the Pearson and Spearman coefficient (+ or -)	*Correlation interpretation*
0.00 to 0.19	*Very weak*
0.20 to 0.39	*Weak*
0.40 to 0.69	*Moderate*
0.70 to 0.89	*Strong*
0.90 to 1.00	*Very strong*

Source: (Campos et al., 2009). (Adapted by the authors).

***Table 4.** Pearson's Correlations*

Correlated Variables	*Correlation Value*	*Correlation Type*
HDI - APIB	*-0.368*	*Weak negative*
APIB - % of accidents of workers (PAT)	*-0.457*	*Moderate negative*
APIB – % of deaths of workers (PMT)	*-0.575*	*Moderate negative*
% accidents of workers (PAT) - % deaths of workers (PMT)	*0.732*	*Strong positive*

However, by using Spearman's method, two of the correlations already analyzed through the Pearson's method were determined to have a higher correlation index. This indicates that the correlation between them is better adjusted to a form other than the linear method. These correlations were between the HDI and the percentage of accidents of workers (PAT) and between the HDI and the APIB.

Other correlations were also found through the Spearman's method, where a strong and direct correlation between PEA and companies and employers in the construction industry (CEC) stands out, pointing out that the two variables grow together, but not at equal rates. (Table 5) shows the results of the variables with significant correlations found through the Spearman's method. Again, based on the values in (Table 3), moderate, strong and very strong correlations were considered as correlations to be taken into account.

***Table 5.** Significant Spearman's Correlations*

Correlated Variables	Correlation Value	Correlation Type
PEA - Companies and employers in construction (CEC)	0.703	Strong positive
PEA - % of accidents of workers (PMT)	0.332	Weak positive
HDI - % of deaths of workers (PAT)	0.318	Weak positive
Companies or employers in construction (CEC) - APIB	-0.334	Weak negative
HDI - APIB	-0.482	Moderate negative

33.3 Ibero-American classification of occupational accidents in the civil construction industry

This section presents 5 classifications of occupational accidents in the civil construction industry; one for each year of the evaluated period. Also, there is an average classification that summarizes the general behavior for the topic in the 5-year period.

Four variables were considered in the creation of the classifications: APIB, HDI, percentage of accidents (PAT) and the percentage of deaths from occupational accidents (PMT). These criteria were taken into account because they were the most significant criteria for occupational accidents and mortality in the civil construction industry, according to the analysis made in section 3.2.

As mentioned in chapter 2, the TOPSIS method was used to establish the classifications. Bearing in mind that the implementation of this method requires assigning a percentage weight to each of the considered criteria, the decision was made to apply the AHP method to determine the value of each of the referred weights.

The AHP method, developed by Professor Thomas Saaty, is one of the most widely used multi-criteria methods in decision-making support for problems with various perspectives (Marins at al., 2009). Initially, for the implementation of the AHP method in this study, a comparative matrix (CM) was created in order to establish the importance of each of the 4 aforementioned criteria. The CM was established under the parameters indicated in (Saaty, 2008) fundamental scale, in which values from 1 to 9 are given to each position of the matrix, depending on the association of the criteria. Here, the values assigned to each CM position were determined by the authors of this study, based mainly on the degree of correlation between variables.

With the CM ready, a normalized comparative matrix (NCM) was created which resulting from dividing each component of the CM into the sum of its respective column. Consequently, the priority eigenvector was calculated by finding the arithmetic mean of each row of the NCM. The value of each of the components of the eigenvector represented the percentage weight of each parameter involved. (Table 6) shows these values.

To complete the application of the AHP method, the consistency of the CM proposed by the authors was verified through the consistency index (CI), using the eigenvalue as a basis. The calculation of the CI was given by an equation proposed by (Saaty, 2008), in which the eigenvalue and the number of criteria evaluated are related. The application of this equation resulted in a CI of 0.0468. Finally, the CI had to be transformed into the consistency rate (CR), obtained by dividing the CI by a constant depending on the size of the matrix. The value of this constant in this case was 0.9, giving a result of 0.0520 for the CR. Based on the above, according to (Saaty, 2008), the CM is considered to be consistent, as well as the results from the application of the AHP method, if the CT is less than 0.10. In this case, the consistency of the results has been verified (Gomede and De Barros, 2012).

Table 6. *Percentage weight of the criteria used in the TOPSIS method.*

	HDI	***Contribution of Construction to the GDP***	***% of Occupational Accidents in Construction***	***% of Deaths in Occupational Accidents in Construction***
Percentage weight	*4.98%*	*10.46%*	*24.33%*	*60.24%*

The TOPSIS method was developed by Ching-lai Hwang and Paul Yoon to evaluate the performance of different alternatives according to a series of criteria. This technique is mainly based on the approach to the ideal solution and the distance to the non-ideal solution, providing a good basis for the creation of classifications without the need to use advanced software (Valladares, 2011).

The process to determine each of the classifications with the TOPSIS method is detailed as follows. First, the decision matrix (DM) was established, where the 4 criteria initially chosen were placed in the columns (HDI, APIB, PAT, PMT) and the alternatives were placed in the rows, which in this case were represented by the countries under analysis. Then, the corresponding data were entered in each position of the matrix, resulting in a 9x4 matrix. Subsequently, the column vector norm was calculated to establish the normalized decision matrix (NDM), obtained by dividing the components of the DM into the norm column for each component. After that, each column was assigned the corresponding percentage weight, according to each criterion. These weights were previously determined using the AHP method. Each component of the NDM was then multiplied by the percentage weight to obtain the weighted normalized decision matrix (WNDM) (Da Costa and Junior, 2013).

In the same sequence, with the determination of the WNDM, the ideal solution and the non-ideal solution could be obtained, assuming that the results closest to the ideal solution were associated with the countries with the best accident behavior, which translates into fewer accidents and deaths. For this reason, the lowest values associated with the percentage of accidents (PAT) and the percentage of deaths (PMT) criteria were considered for the ideal solution. The same applies to the HDI because of its direct correlation with the percentage of accidents at work (PAT). For APIB, the highest value was considered to be the best result for the ideal solution as this is inversely correlated with accident rates, which means that the higher the APIB, the fewer accidents, and deaths, probably because the higher the production, the greater the investment in safety in the construction sector. As for the non-ideal solution, the opposite values to the positive ideal solution were considered.

Based on the ideal and non-ideal solution, it was possible to determine the distances to these solutions presented by each country, which in turn allowed the calculation of the relative proximity (RP) to the ideal solution, which is a value dependent on the previously calculated distances.

To complete the application of the TOPSIS method, the classification was made with the resulting value of the RP, with the countries in the top positions showing the best performance in terms of occupational injuries. In contrast, the countries in the last positions were the ones that showed the worst behavior, presenting the highest rate of deaths and accidents (Krohling and De Souza, 2011). Based on the above, (Table 7) shows the classifications obtained. Regarding the classifications, Peru, Uruguay and Spain present the best results. This seems to indicate that they are the leading countries in Ibero-America in dealing with the problem of occupational injuries in construction. On the other hand, Colombia, Portugal and Argentina show the worst performance. It is important to mention the presence of Portugal in these last ranking positions, as it was expected to have a better performance against occupational accidents since it is a first-world country and, in theory, with stricter bases for the implementation of occupational safety policies.

Table 7. *Ranking of occupational injuries in the construction industry*

	2013	**2014**	**2015**	**2016**	**2017**	**Average**
1	Peru	Peru	Uruguay	Uruguay	Uruguay	PERU
2	Uruguay	Uruguay	Peru	Peru	Peru	URUGUAY
3	Spain	Spain	Spain	Spain	Spain	SPAIN
4	Brazil	Chile	Chile	Mexico	Chile	CHILE
5	Portugal	Mexico	Brazil	Brazil	Mexico	BRAZIL
6	Mexico	Brazil	Colombia	Chile	Colombia	MEXICO
7	Chile	Colombia	Mexico	Colombia	Brazil	COLOMBIA
8	Colombia	Portugal	Portugal	Portugal	Portugal	PORTUGAL
9	Argentina	Argentina	Argentina	Argentina	Argentina	ARGENTINA

Finally, (Table 8) shows some basic characteristics and obligations of employers related to the prevention of occupational accidents in each country under study. In general, it can be observed that most of the countries have similar obligations.

In terms of the characteristics and obligations associated with the prevention of occupational accidents, based on the study carried out by (Martínez-Aires et al., 2015), it can be observed that in recent years, there has been little evolution in the basic aspects. However, these characteristics and obligations have worked efficiently, as a decreasing trend in accident figures was shown in the civil construction industry.

Table 8. *Basic characteristics and obligations of employers in the Ibero-American countries under study in terms of prevention of occupational accidents*

Yes / No	Argentina	Brazil	Chile	Colombia	Spain	México	Peru	Portugal	Uruguay
Are there SHAW standardization agencies?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are there SHAW related laws?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the employer obliged to provide the employees with the right working tools?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the employer obliged to define, disclose, direct and enforce the SHAW policy within the company?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the employer obliged to conduct SHAW prevention, promotion, and training?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Is the employer obliged to carry out at least an annual workplace risk assessment and renewal of the SHAW plan?	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Is the employer required to keep an accident record?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

4. Conclusions

Based on the results obtained in this study, it can be concluded that, although the countries analyzed show some differences in their policies, in their level of development and in the way they collect the data, in general, all of them show concern for the problem of occupational injuries and present strategies to reduce them. This is reflected in the research results, where a decrease in the number of accidents and deaths was observed.

However, it should be clarified that despite the analyzed data were obtained from official agencies, it may not fully represent the reality of the industry because of the great informality and outsourcing existing in the construction industry that to some extent distorts the collection of data by the sources. For the specific case of Argentina, Chile and Portugal, the organization and the greater number of criteria presented in their statistics should be recognized.

Considering all of the above, it is recommended that the quality of data associated with occupational accidents be standardized and enhanced in all countries since the same parameters would be available for studies, which would provide a more uniform picture. Similarly, it is suggested that SHAW entities in each country should be stricter in verifying compliance with the laws to maintain and continue to decrease the number of contingencies since there are still significant gaps between what the law recommends and what is actually applied in the workplace.

It is important to remember that the problem of accidents is partly a result of the great risk implicit in the work of civil construction. However, the vast majority of accidents can be avoided if companies comply with the law and provide the basic means for prevention, if the state intensifies controls and if workers follow preventive measures, respect safety standards and are aware that physical integrity and life are at stake.

Finally, it is suggested to continue this work including more countries of the region and segmenting the sample in the construction sub-sectors, aiming at identifying the sub-sectors that present more influence on the problem. It is also recommended to extend the period of study to check whether the improvement seen in the period 2013-2017 continued in the following years.

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