



## THE GUATEMALAN CONSTRUCTION CHARACTERIZATION OF THE PERCEIVED RISK BY MANAGERS OF SUFFERING WORK ACCIDENTS

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**Abstract.** The construction industry is considered one of the highest risk production sectors, even more so in developing countries such as Guatemala. A characterization has been carried out on the perception of Guatemalan construction company managers regarding, the risk of accidents exist for the different activities they perform. The characterization has been carried out on a representative sample of the business population via a questionnaire. A preliminary data analysis was performed followed by a Descriptive and a Multiple Correspondence Analysis. Companies are characterized as “medium-size” companies, with an average of 81.1 construction workers per year and average annual turnover of 1.29 million euros. 4 clusters of construction activities occur with similar accident weightings. Companies in Cluster 1 are associated to the variables grouped with a Low risk weighting, with a medium to high number of on-site workers and with a turnover of more than 100,000 euros. In contrast, those in Cluster 2 are associated with the variables grouped as having a Medium risk weighting, with a low number of on-site workers and a turnover of less than 100,000 euros. The companies in Cluster 3 are only associated with High risk weighted. And those of Cluster 4 with Not applicable risk-weighting variables.

**Keywords:** Guatemala, health and safety, perception, construction, accidents, companies.

### Introduction

The construction industry is considered one of the highest risk production sectors given that accident rate stays continuously high over time (Hassan et al., 2007; Pérez-Alonso et al., 2012; Rodríguez-Garzón & López-Alonso, 2013; Sousa et al., 2014; Carrillo-Castrillo et al., 2017; Hernández-Arriaza et al., 2018; Liang et al., 2018; Yuan et al., 2018; Fagnoli & Lombardi, 2019; Peng & Chan, 2019; Ayhan et al., 2020; Mihić, 2020). To prevent accidents, it is necessary to carry out exhaustive maintenance, regular safety inspections, continuous safety training and develop an accident investigation plan (Goh et al., 2016). In addition, there are companies that not only possess such controls, but also highlight them to have greater rel-

evance amongst companies that work with transparency and wish to obtain greater legitimacy (Berry et al., 2009). However, this is not always the case, the reason being an increase in the work cost (Yilmaz & Kanit, 2018) – this results in significant economic and social impact, in many cases, even on-the-job training of staff is avoided (Cheng et al., 2010). Moreover, older workers are taken on, which in turn, means they are more likely to suffer accidents with a higher proportion of fatalities (Chiang et al., 2018). There are studies that link a company’s accident rate to its own economic performance (Forteza et al., 2017). Thus, a significant positive linear relationship was obtained between the site risk and the accident rate, as well as a

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significant quadratic relationship (an inverted U-shape) between the accident rate and the economic performance of the company.

The determinant factors for this high accident situation can be found in the peculiarities of the construction sector (Cheng et al., 2010). Indeed, the combination of aspects – such as frequent employee turnover, outsourcing and strict contract deadlines, outdoor work in all weather conditions, the lack of highly skilled workers, the use of obsolete work equipment and frequent changes of job sites as well as the presence of different companies working on the same job site simultaneously – all contribute to the high accident and injury rate (Carrillo-Castrillo et al., 2017).

To control the high accident rate caused by the interaction of these multiple factors, adequate safety management is necessary along with a causal accident analysis (Hernández-Arriaza et al., 2018; Wong et al., 2018). Likewise, hazard identification in the construction industry is subject to a larger number of variables and unknowns than in other manufacturing industries making the hazard identification process more difficult and resulting in many injuries and fatalities (Mihic, 2020).

According to Solís-Carcaño and Franco-Poot (2014), psychological science defines perception as a cognitive process, inferential and constructive in character, by which a subject can generate an internal representation of what happens externally, based on information collected by the senses along with memory information. Several studies have shown that, in general, the perceptions of management and workers differ so it is interesting to understand the perceptions of a construction company's management safety practices both from the managers' own standpoint and from that of the workers (Wei et al., 2002; Reese & Eidson, 2006). For the latter, the work of Gillen and collaborators (Gillen et al., 2004) stands out, in which workers identified the management's commitment to safety, their concern for workers, the consistency between spoken messages and practice, professionalism and communication skills as key qualities in successful managers. Mohamed (2002) also indicates that the safety environment on construction sites is closely related to the workers' perceptions and beliefs regarding the safety issue.

Accidents occur due to three main causes (Abdelhamid & Everett, 2000): not identifying unsafe conditions before starting a job, continuing to work on-site even though someone has identified unsafe conditions, and deciding to act in an unsafe way regardless of the workplace conditions. The latter two causes are clear examples of perceived reality being a strong component that can influence workers' behaviour (Solís-Carcaño & Franco-Poot, 2014). In many cases, it is believed that the construction personnel themselves must possess their own innate risk perception and that this should be enough to avoid accidents; however, nothing is further from the truth because, at the very least, the training variable significantly alters the risk

(Rodríguez-Garzón et al., 2014, 2016) and the worker's age variable varies risk perception between younger and older workers (Peng & Chan, 2019; Idrees et al., 2017), among other variables.

On the other hand, more attention needs to be paid to construction tasks and activities (Rodríguez-Garzón & López-Alonso, 2013), given that task-level studies account for only 2.28% of all health and safety research in the construction industry (Zhou et al., 2015). There is a lack of workplace risk-exposure measurements done in the field because most research tends to be epidemiological and focused primarily on accidents (Swuste et al., 2015). Thus, in a study with construction workers in Spain (Rodríguez-Garzón & López-Alonso, 2013), it was shown that the job or construction task performed by the worker, presented statistically significant differences with respect to what they thought about the risk knowledge of their work that those responsible for the company have.

Guatemala is no exception – according to hospital registers of IGSS accidents (2016), amongst the manufacturing-construction-service sectors in 2016, 28.15% of accidents corresponded to construction; while in 2017, it accounted for 24.75%. As in any developing country, the risk of health loss is 10 to 20-times higher than in industrialized nations (Dong, 2005; Tadesse & Israel, 2016). Construction workers in Guatemala are six times more likely to die on the job than their counterparts in Switzerland (International Labour Organization [ILO], 2001), so strategic priority should be given to their safety (ILO, 2008), especially because the annual construction growth in Guatemala was 2.7% in 2017 and 3.1% in 2018 (Cámara Guatemalteca de la Construcción, 2018). There is a register of 7,720 construction companies (Directorio Nacional Estadístico de Empresas [DNEE], 2015) comprising micro, small, medium and large-scale companies, more than 50% of which are concentrated in the Guatemala department although the majority of their operations are reported as being in other regions of the country.

For this reason, Hernández-Arriaza et al. (2018) characterized occupational risk prevention in Guatemala's construction industry, correlating organizational parameters and the size of the company with parameters for health and safety prevention and management activities both in the company and on site. But the perception of accident risk was not characterized in the different construction tasks or activities carried out in the Guatemalan construction industry according to their managers. However, as Wei et al. (2002) indicate, it is interesting to know the perceptions from safety practices of the management in the construction company.

For all these reasons, the objective of this work is to characterize the perception of accident risk that managers of the Guatemalan construction industry have in the different construction tasks or activities that they carry out in their construction activity.

## 1. Materials and methods

### 1.1. Research design and data analysis

To characterize the perception of Guatemalan construction company managers regarding the accidents their workers might suffer, and which risks exist that cause accidents in the different construction activities carried out, the following study variables have been adopted: 5 general company variables (annual company turnover (C), the number of office workers (D), the number of on-site workers (E), the number of work crews per year (F), the number of years working on site (G)) and 64 accident risk weighting variables (see Tables 1 and 2). In Tables 1 and 2, all the variables are shown and the nomenclature for the variables and their categories are explained.

Field data acquisition was carried out by sampling Guatemalan construction companies using a questionnaire designed for the purpose. Once the data were obtained, a preliminary data analysis was performed, along with a descriptive analysis of the studied variables, determining the frequencies (%) for qualitative and mean values, and the standard deviation (s.d.) for quantitative values. In addition, a multiple correspondence analysis was carried out with the 64 accident-risk weighting variables for the different construction activities and the 5 general company variables, allowing us to determine clusters of construction activities with similar weightings in which accidents occur.

Finally, to assess the possibility of bias produced by the non-response of the companies to which the questionnaire was sent and did not answer, an analysis of simple variance (ANOVA) was carried out for the 3 most significant quantitative variables of the study (annual company turnover, number of office workers, number of on-site workers), for the top 20 and the last 20 respondents. These 3 variables were considered the most significant of the 5 general variables (quantitative) of the company studied, because they presented higher correlations with the 64 qualitative variables. All data analysis was performed with the SPSS Statistics V17.0 program.

### 1.2. Sampling of Guatemalan construction companies

#### 1.2.1. Company census

Guatemalan construction companies as a whole were considered in the population study, of which there were 7,720 as of December 2015, according to data from Guatemala's National Statistical Institute (DNEE, 2015). However, in order to have reference data for them, data from Guatemala's Ministry of Communications, Infrastructure and Housing (MICIVI) was taken as a census sample; this showed 1,954 companies as of December 2015.

#### 1.2.2. Technique and sampling questionnaire

To carry out the sampling, a simple random sampling technique was used and a specific questionnaire was de-

signed to collect the information. This was structured into 2 sections (or groups of variables):

1. General company data: 5 variables (see Section 1.1).
2. The weighting for suffering an accident in 64 different construction activities: 64 variables (see Tables 1 and 2).

The weightings for suffering an accident are: 1. Low; 2. Medium; 3. High and 4. None or Not applicable. All the variables and their nomenclature are shown in Tables 1 and 2.

#### 1.2.3. Sample size, sampling plan and data collection system

The sample size, sampling plan and data collection system is the same as that performed by Hernández-Arriaza et al. (2018). Three hundred and fifty surveys were sent to Guatemalan construction companies, of which 100 were completed and returned with significant responses for analysis. The sampling phase took place from March 2016 to December 2017.

## 2. Results

### 2.1. Descriptive analysis

#### 2.1.1. General company characteristics

The companies studied show an average annual turnover (C) of 1.29 million euros (s.d. 6.29), an average number of office workers (D) of 7.3 (s.d. 15.06), an average number of on-site workers (E) of 81.1 (s.d. 75.22), an average number of work crews each year (F) of 6.8 (s.d. 5.55) and the companies involves in on-site work (G) for an average of 15.0 years (s.d. 7.53).

#### 2.1.2. Guatemalan construction company managers' perception regarding the risk of their workers suffering an accident

As Tables 1 and 2 show the weighting frequencies of suffering an accident for each of the 64 different construction activities that might be performed in the Guatemalan construction industry.

As Tables 1 and 2 show, the construction activities that stand out as indicating a Low risk probability would be: plotting, delineation and demarcation (R5) (85.6%), topographical lifting and levelling (R1) (82.7%), temporary water piping preparation (R42) (78.5%), PVC water supply connections and networks (R9) (77.1%) and galvanized iron water supply connections and networks (R10) (75.8%), among others. The construction activities that stand out as indicating a Medium risk probability would be: using scaffolding at different heights (R18) (64.6%), trench making or digging (R14) (60.8%), using heavy machinery for earth movement (R12) (58.8%), prefabricated roof structures (joists and vault) (R32) (58.3%) and low-voltage power connections and grids (R50) (55.9%), amongst others.

Table 1. Frequencies of the 64 risk-weighting variables in each construction activity (Part 1)

Variables	Nom.*	Weighting			
		1. Low	2. Medium	3. High	4. None or Not applicable
Topographic lifting and levelling	R1	82.7	14.3	3.0	0.0
Coating and cleaning of the work area	R2	63.3	31.6	4.1	1.0
Using a sharp tool	R3	35.1	51.5	11.3	2.1
Perimeter encirclement	R4	59.2	33.7	3.1	4.0
Plotting, delineation and demarcation	R5	85.6	10.3	3.1	1.0
Protection of slopes with geogrids	R6	23.5	50.0	20.4	6.1
Making and placing gabions	R7	17.7	44.8	29.2	8.3
Placing retaining walls	R8	11.6	49.5	34.7	4.2
PVC water connections and water networks	R9	77.1	13.5	6.3	3.1
Galvanized iron water connections and networks	R10	75.8	12.6	3.2	8.4
Drilling and placing piles	R11	26.0	43.8	21.9	8.3
Use of heavy machinery for earthmoving	R12	15.5	58.8	20.6	5.1
Demolition and using demolition equipment	R13	17.7	55.2	25.0	2.1
Trench digging or excavation	R14	20.6	60.8	18.6	0.0
Soil compaction	R15	55.7	37.1	4.1	3.1
Making iron frames or structures	R16	63.5	26.0	8.3	2.2
Making and placing scaffolding	R17	42.6	42.6	14.8	0.0
Using scaffolding at different heights	R18	9.4	64.6	26.0	0.0
Raising masonry walls	R19	49.5	38.9	8.4	3.2
Placing prefabricated walls	R20	57.9	31.6	6.3	4.2
Placing plasterboard walls	R21	77.9	10.5	5.3	6.3
Picking and reworking walls and ceilings	R22	73.7	17.9	5.3	3.1
Application of finishes on walls and ceilings	R23	71.6	20.0	5.3	3.1
Casting of flat spacious areas (floors and slabs)	R24	66.7	26.0	5.2	2.1
Cutting and sealing concrete joints (concrete)	R25	44.8	44.8	7.3	3.1
Casting of reduced structures (columns and beams)	R26	70.2	23.4	3.2	3.2
Using a mixer (concrete)	R27	55.8	37.9	3.2	3.1
Using concrete vibrators (concrete)	R28	67.7	25.0	4.2	3.1
Use of concrete pumping equipment (concrete)	R29	47.9	45.8	1.0	5.3
Using concrete levelling equipment (concrete)	R30	68.8	21.9	5.2	4.2
Concrete pumping or injection (concrete)	R31	59.4	32.3	3.1	5.2
Prefabricated roof structures (joists and vault)	R32	20.8	58.3	17.7	3.2

Note: \*Nom.: Nomenclature.

As for the 3 construction activities that stand out as having a High-risk probability, these are: high voltage electrical connections and networks (R51) (45.1%), using cranes and loading booms (R53) (38.4%) and using manual, electric or combustion lifts (R51) (27.8%).

Finally, the 6 construction activities highlighted because they are indicated as having “None or Not applicable” risk probability are: railway track installation (R56) (79.2%), gas, fuel or petroleum pipelines (R57) (76.6%), mining activities (R64) (76.3%), mining tunnel structures (R59) (75.3%), tunnel excavation (R58) (50.0%) and river, lake or sea dredging (R63) (46.2%).

## 2.2. Multiple correspondence analysis

This epigraph shows the results of the multiple correspondence analysis performed on the 64 risk-weighting

variables and the 5 general company variables (Tables 3 and 4). A two-dimensional model has been obtained summarizing the information for all the analysed variables. For interpretation purposes, the model generates the following parameters (the results of which are presented below): Measures of discrimination, quantifications and object (company) scores.

As already indicated, the model obtained has two significant dimensions and provides adequate reliability since the first dimension explains 39.8% of the variance with a Cronbach's  $\alpha$  coefficient of 0.978 and eigenvalue of 27.491 while the second explains 29.7% of the variance with a Cronbach  $\alpha$  coefficient of 0.965 and a eigenvalue of 20.505. For the factorial model as a whole, the average for the explained variance is 34.8%, the mean coefficient of Cronbach's  $\alpha$  is 0.972 and the average eigenvalue is 23.998.

Table 2. Frequencies of the 64 risk-weighting variables in each construction activity (Part 2)

Variables	Nom.*	Weighting			
		1. Low	2. Medium	3. High	4. None or Not applicable
Steel-frame building structures	R33	10.6	55.3	21.3	12.8
Using a manual tool (in general)	R34	62.2	31.6	6.2	0.0
Making stairs or stands	R35	54.2	38.5	5.2	2.1
Using mobile stairs	R36	32.3	48.4	16.1	3.2
Using electrical equipment	R37	42.7	45.8	11.5	0.0
Use of combustion equipment	R38	45.2	43.0	9.7	2.1
Use of welding equipment in general	R39	33.3	48.4	12.9	5.4
Using and driving trucks	R40	51.6	37.6	7.5	3.3
Loading and unloading construction materials	R41	50.0	39.4	7.4	3.2
Temporary water piping preparation	R42	78.5	16.1	5.4	0.0
Preparation of temporary electrical lines	R43	72.3	23.4	4.3	0.0
Installing floors and tiles	R44	75.5	17.0	4.3	3.2
Making and hanging metal or wooden doors	R45	75.3	16.1	6.5	2.1
Making and hanging metal or wooden windows	R46	58.1	31.2	8.6	2.1
Preparation and laying of asphalt	R47	34.4	36.7	4.4	24.5
Preparation and placement of solid pavement	R48	48.9	41.5	5.3	4.3
Articulated pavement installation (cobblestones)	R49	53.2	39.4	2.1	5.3
Low-voltage power connections and power grids	R50	22.6	55.9	7.5	14.0
High-voltage power connections and power grids	R51	6.6	19.8	45.1	28.5
Use of a manual, electric or combustion lift	R52	26.7	23.3	27.8	22.2
Using cranes and loading booms	R53	14.3	36.3	38.4	11.0
Use of manual, electric or combustion forklifts	R54	26.4	38.5	23.1	12.0
Driving small and medium-sized vehicles on site	R55	56.5	35.9	5.4	2.2
Installation of railway tracks	R56	6.5	11.7	2.6	79.2
Gas, fuel or oil line installation	R57	7.8	11.7	3.9	76.6
Tunnel excavation	R58	7.0	5.8	37.2	50.0
Mining tunnel structures	R59	3.9	1.3	19.5	75.3
Absorption wells	R60	6.4	50.0	38.3	5.3
Inspection wells for storm or sanitary drainage	R61	18.7	49.5	26.4	5.4
Septic tank construction	R62	18.3	53.8	25.8	2.1
River, lake or sea dredging	R63	12.5	17.5	23.8	46.2
Mining activities	R64	3.9	5.3	14.5	76.3

Note: \*Nom.: Nomenclature.

Tables 3 and 4 show the discrimination measures for each variable with respect to each of the two dimensions and the mean. If these values are represented in an orthogonal axis system, a discrimination measure figure is obtained for the variables in the model, as shown in Figure 1, where you can observe the correlations of the variables. It should be noted that there is greater correlation between variables if the angle formed by the lines that join the origin of the coordinates with each of the variables is small for each pair of variables analysed; conversely, if the angle is very large between two variables, this indicates that a good correlation does not exist between them.

As for the model discrimination measures obtained in Tables 3 and 4, one can see that R22 (0.692) is the leading variable in the explanatory variables ranking since it presents the highest mean discrimination; this is followed, in

order of descending explanation, by variables R23 (0.671), R26 (0.665), R24 (0.620), R25 (0.615) and R27 (0.601). The least explanatory variable is D (0.010) followed by F (0.077), R14 (0.084) and R36 (0.122).

With regard to discrimination in both dimensions, the first dimension has very large discriminations with variables R27 (0.883), R32 (0.878), R25 (0.866), R26 (0.864) and R48 (0.852), while the second dimension presents large discriminations with variables R22 (0.722), R21 (0.620), R41 (0.618) and R17 (0.526) but lower than in dimension 1.

In addition, similar discrimination measures for a variable in the two dimensions reflect difficulties in assigning it to a given dimension. Ideally, a variable has a high value in a single dimension and a low value in the other, as with variables R7, R8, R29, R60, R61, and R62,

which correlated more with dimension 1, and therefore this dimension better discriminates against the categories for these variables; whereas variables R17, R34, R37, R41, R43, R57, and R59 are more correlated with dimension 2, so this dimension better discriminates against the categories for these variables.

It should be noted that the 5 general company variables are not significant in the mathematical model obtained because the discriminations in both dimensions are very small and close to the origin of the coordinates, and none clearly correlate to either of the 2 dimensions. However, Figure 1 shows which of the 64 risk-weighting variables correlate with each of the general company variables. Hence, the company's annual turnover (C) variable and number

of years that the company has been working on sites (G) variable correlate with the risk-weighting variables found in the circular sector ranging from R17 to R21, while the number of work crews for the company per year (F) variable aligns with variable R21 and all the others align with the R21 variable. Likewise, the number of company workers (E) variable correlates with the risk-weighting variables found in the circular sector from R21 to R27. Conversely, the number of company office workers (D) variable does not clearly correlate with any risk-weighting variable since it is located practically at the coordinate origin.

In addition, the model obtained allows us to identify the categories for each variable that most discriminates the objects (companies) thus, the quantifications of the

Table 3. Measures of discrimination of the 64 risk-weighting variables for each construction activity and the general company variables for each dimension (Part 1)

Variables	Nomenclature variables	Dimension		Average
		1	2	
Topographic lifting and leveling	R1	0.191	0.259	0.225
Coating and cleaning of the work area	R2	0.076	0.330	0.203
Using a sharp tool	R3	0.226	0.365	0.296
Perimeter encirclement	R4	0.268	0.342	0.305
Plotting, delineation and demarcation	R5	0.029	0.359	0.194
Protection of slopes with geogrids	R6	0.629	0.038	0.333
Making and placing gabions	R7	0.546	0.077	0.311
Placing retaining walls	R8	0.746	0.053	0.399
PVC water connections and water networks	R9	0.676	0.418	0.547
Galvanized iron water connections and networks	R10	0.472	0.311	0.391
Drilling and placing piles	R11	0.433	0.094	0.263
Use of heavy machinery for earthmoving	R12	0.356	0.196	0.276
Demolition and using demolition equipment	R13	0.584	0.213	0.399
Trench digging or excavation	R14	0.071	0.096	0.084
Soil compaction	R15	0.385	0.432	0.409
Making iron frames or structures	R16	0.568	0.560	0.564
Making and placing scaffolding	R17	0.007	0.526	0.266
Using scaffolding at different heights	R18	0.046	0.311	0.179
Raising masonry walls	R19	0.542	0.466	0.504
Placing prefabricated walls	R20	0.672	0.418	0.545
Placing plasterboard walls	R21	0.378	0.620	0.499
Picking and reworking walls and ceilings	R22	0.683	0.701	0.692
Application of finishes on walls and ceilings	R23	0.680	0.663	0.671
Casting of flat spacious areas (floors and slabs)	R24	0.705	0.535	0.620
Cutting and sealing concrete joints (concrete)	R25	0.866	0.364	0.615
Casting of reduced structures (columns and beams)	R26	0.864	0.466	0.665
Using a Mixer (concrete)	R27	0.883	0.319	0.601
Using Concrete Vibrators (concrete)	R28	0.754	0.327	0.540
Use of concrete pumping equipment (concrete)	R29	0.638	0.095	0.367
Using concrete levelling equipment (concrete)	R30	0.729	0.322	0.525
Concrete pumping or injection (concrete)	R31	0.639	0.247	0.443
Prefabricated roof structures (joists and vault)	R32	0.878	0.297	0.588

variables are obtained and represented on a factorial plane (Figure 2). Category quantifications are the average scores for objects in the same category (Hernández-Arriaza et al., 2018). Figure 2 shows the positions of the four possible categories (1. Low, 2. Medium, 3. High and 4. None or Not applicable) for the risk-weighting variables that have measure of discrimination averages greater than 0.5; this makes the figure clearer because, if the 64 weighting variables were included, the values would overlap with

each other and the representation would be confusing.

Using the Factorial Plane representation (Figure 2), one can observe the correlations (or correspondences) of the variable categories. One can see how the 4 risk-weighting variable categories, together with the 5 general company variable categories are grouped into 4 clusters.

Finally, the obtained model allows the objects (companies) to be represented on a factorial plane using each of their scores in each of the two dimensions (Figure 3).

Table 4. Measures of discrimination of the 64 risk-weighting variables for each construction activity and the general company variables for each dimension (Part 2)

Variables	Nomenclature variables	Dimension		Average
		1	2	
Steel-frame building structures	R33	0.386	0.226	0.306
Using a manual tool (in general)	R34	0.003	0.474	0.239
Making stairs or stands	R35	0.701	0.329	0.515
Using mobile stairs	R36	0.070	0.174	0.122
Using electrical equipment	R37	0.029	0.442	0.236
Use of combustion equipment	R38	0.582	0.263	0.422
Use of welding equipment in general	R39	0.753	0.431	0.592
Using and driving trucks	R40	0.418	0.454	0.436
Loading and unloading construction materials	R41	0.159	0.618	0.389
Temporary water piping preparation	R42	0.684	0.179	0.431
Preparation of temporary electrical lines	R43	0.028	0.398	0.213
Installing floors and tiles	R44	0.669	0.352	0.510
Making and hanging metal or wooden doors	R45	0.701	0.346	0.523
Making and hanging metal or wooden windows	R46	0.712	0.318	0.515
Preparation and laying of asphalt	R47	0.165	0.227	0.196
Preparation and placement of solid pavement	R48	0.852	0.258	0.555
Articulated pavement installation (cobblestones)	R49	0.703	0.176	0.439
Low-voltage power connections and power grids	R50	0.070	0.204	0.137
High-voltage power connections and power grids	R51	0.105	0.135	0.120
Use of a manual, electric or combustion lift	R52	0.230	0.090	0.160
Using cranes and loading booms	R53	0.298	0.133	0.216
Use of manual, electric or combustion forklifts	R54	0.209	0.081	0.145
Driving small and medium-sized vehicles on site	R55	0.216	0.486	0.351
Installation of railway tracks	R56	0.030	0.304	0.167
Gas, fuel or oil line installation	R57	0.032	0.459	0.245
Tunnel excavation	R58	0.106	0.223	0.165
Mining tunnel structures	R59	0.043	0.400	0.221
Absorption wells	R60	0.568	0.081	0.325
Inspection wells for storm or sanitary drainage	R61	0.568	0.058	0.313
Septic tank construction	R62	0.704	0.051	0.378
River, lake or sea dredging	R63	0.112	0.138	0.125
Mining activities	R64	0.043	0.434	0.239
Annual company billing	C	0.054	0.197	0.126
Number of workers of the company	E	0.169	0.172	0.170
Number of company office workers	D	0.007	0.014	0.010
Number of crews each year	F	0.055	0.100	0.077
Number of years working in construction	G	0.035	0.261	0.148
	Active Total	27.491	20.505	23.998

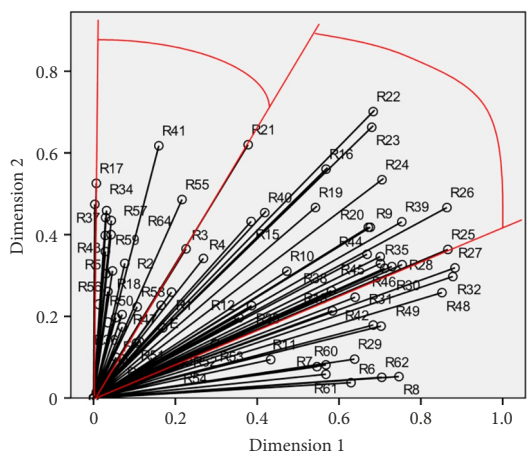


Figure 1. Representation of measures to discriminate variables at the two-dimensional level (see variables nomenclature in Tables 3 and 4)

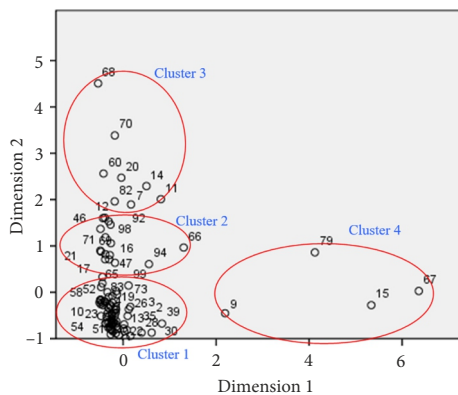


Figure 3. Bi-space scatter plot of companies

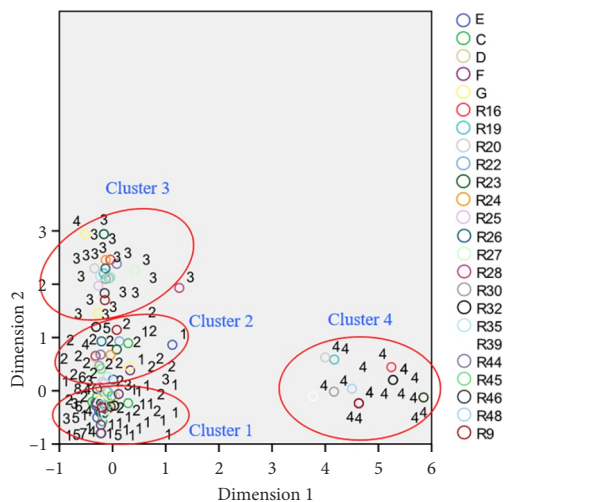


Figure 2. Factorial plane of the quantification the variable categories (Categories of risk-weighting variables that have total mean discriminations greater than 0.5: 1. Low, 2. Medium, 3. High and 4. None or not applicable) and general company variables (see variables nomenclature in Tables 3 and 4)

Based on the scores of the objects obtained for each company in the mathematical model developed (represented in Figure 3), one can see how the sample companies are grouped into 4 clusters with homogeneous company characteristics, and are also associated with the 4 clusters of variable categories described above in Figure 2.

Table 5 describes the characteristics of these 4 clusters identified in Figures 2 and 3.

### 3. Discussion

#### 3.1. Response rate and sampling bias

In accordance with the sampling plan, 350 surveys were conducted, of which 100 valid survey responses were received, making the effective response rate 28.57%, which is slightly less than the 38.0% obtained by Chen and Mohamed (2009) in Hong Kong for a sampling study of construction contracting companies, and well below the 61.11% obtained by Idrees et al. (2017) for a study looking at workplace safety perception on 5 construction projects in Pakistan.

Table 6 shows the results of the analysis of variance carried out to verify the non-existence of non-response

Table 5. Description of the characteristics of the clusters identified in Figures 2 and 3

Variables	Dimension	Clusters			
		Cluster 1	Cluster 2	Cluster 3	Cluster 4
Figure 2					
Amplitude of the range of values for each cluster	Dimension 1	[-1,1]	[-1,1.2]	[-1,1.4]	[2,6]
	Dimension 2	[-1,0.3]	[0.3,1.4]	[1.4,3.3]	[-0.5,0.8]
Risk-weighting		Low	Medium	High	None or Not applicable
Number of years working on site		Categories: 1-10/11-20/21-30	>40	31-40	-
Number of office workers		Categories: <6/6-10/11-20	>20	-	-
Number of on-site workers		All categories >11	<11	-	-
Annual company turnover		All categories >100,000 €	<100,000 €	-	-
Figure 3					
Amplitude of the range of values for each cluster	Dimension 1	[-1,1]	[-1,1.4]	[-0.5,1.1]	>2.0
	Dimension 2	[-1,0.3]	[0.5,1.2]	[1.7,4.5]	[-1.0,0.7]
Risk-weighting		Low	Medium	High	None or Not applicable



Table 6. Verification of non-response bias in sampling (ANOVA analysis)

Variables	Top 20 respondents	Last 20 respondents	Other respondents
Annual company turnover (millions of euros) (p-value: 0.058)*	0.48 (0.29)	5.29 (16.8)	0.71 (0.98)
Number of office workers (p-value: 0.135)*	5.15 (2.99)	13.30 (32.58)	6.00 (3.65)
Number of on-site workers (p-value: 0.065)*	76.05 (77.31)	48.9 (87.07)	93.86 (67.65)

Note: \* Significance level for mean differences with the Bonferroni post-hoc test ( $p < 0.05$ ).

bias in the sampling phase. It is observed that the p-value for the three variables analyzed is greater than 0.05, so there are no statistically significant differences between the 3 groups of respondents.

### 3.2. General company characteristics

Guatemalan construction companies have an average annual turnover (C) of 1.29 million euros (s.d. 6.29), which almost coincides with the average annual turnover of greenhouse companies in south-eastern Spain – 1.56 million euros (Pérez-Alonso et al., 2011). Furthermore, the average number of office workers (D) in Guatemalan construction companies is 7.3 (s.d. 15.06) and the average number of on-site workers (E) is 81.1 (s.d. 75.22), of which 39.2% are small businesses, 49.5% are medium-sized and 11.3% are micro-enterprises – this is very similar to the 14.0% of companies as a whole in the Andalusian construction sector (Spain) (Calderón-Gálvez, 2006), but far from the 50.0% of micro-enterprises in the greenhouse construction sector in south-eastern Spain (Pérez-Alonso et al., 2011). The average number of on-site work crews each year (F) making up Guatemala's construction companies is 6.8 (s.d. 5.55), a higher value than the 4.4 (s.d. 2.59) for greenhouse construction companies in south-eastern Spain (Pérez-Alonso et al., 2011). Finally, the average number of years that Guatemalan construction companies have been working on site (G) is 15.0 years (s.d. 7.53).

### 3.3. The perception of Guatemalan construction company managers regarding the risk of their workers suffering an accident

#### 3.3.1. Descriptive analysis

When analysing the results for the risk weighing of workers suffering an accident in the different construction activities or tasks (64 variables) carried out by Guatemalan construction companies, it should be noted that, of the 64 activities studied, in 35 (54.7%) the risk weighing was indicated as being Low; in 20 (31.3%) it was Medium; in 3 (4.7%) it was High and in 6 (9.4%) it was None or Not applicable. This significant percentage of companies that have a Low or Medium risk weighing for suffering on-site construction accidents clearly indicates the minimal company management and training on accident risks given to workers, as shown by Rodríguez-Garzón et al. (2014, 2016), who stated that, when workers receive low levels of training, they have less risk perception; in contrast, when there is adequate, high-level training, workers have greater risk perception. This is the case for construction compa-

nies in Guatemala – 42.4% of them do provide training whereas 53.6% indicate that they only provide it sometimes (Hernández-Arriaza et al., 2018), which does not ensure it occurs and is the cause of safety shortcomings (Tam et al., 2004). Also, Solís-Carcaño and Franco-Poot (2014) looking at medium, small and micro construction companies in Mexico (which account for 97% of the sector overall) indicated that these companies do not provide the minimum safety or training conditions, nor do they establish risk prevention programmes; they added that the argument often made to justify this situation is that such companies face the permanent challenge of simply trying to survive. Furthermore, they state that the perception of a particular reality in the workplace is a strong component that can influence worker behaviour. Likewise, in a study with construction workers in Spain (Rodríguez-Garzón & López-Alonso, 2013), it was concluded that the workers who carry out the structures (structural workers) have more training than the group of masonry workers; additionally, the greater the training received by the worker, the lower the trust in the health and safety head of the company. In addition, as Hinze (1997) pointed out, the perception of worker safety and individual safety behaviour is affected by demographic factors such as gender, age, experience, education, employment level, marital status and the number of dependent family members. In this sense, Idrees et al. (2017), in a study of construction workers in Pakistan, found that older workers are more aware of safety while young workers have more accidents; moreover, workload and job satisfaction are significantly dominant factors in the safety perception of older workers, while organizational relationships, mental stress and job security are dominant factors for younger workers.

In addition, several authors highlighted the need to analyse the particular characteristics of the tasks or work activities carried out in construction (Hassan et al., 2007; Mitropoulos et al., 2009; Rodríguez-Garzón & López-Alonso, 2013; Di Pasquale et al., 2015; Sadeghi et al., 2015; Fargnoli et al., 2018). Mitropoulos et al. (2009) justified this need since regulatory approaches do not adequately consider the characteristics of work processes. Hassan et al. (2007) in a comparative construction safety study on large and small-scale projects revealed that large-scale projects showed a high and consistent level of safety whereas small ones had low and varied levels of safety. The determinants for these differences in safety levels were organizational commitment, factors influencing workmate communication, worker-related factors, personal-role and supervisor-role factors, safety barriers and safety behav-

ious factors as well as management commitment at all levels in accordance with the management structure and the behaviour in the taking of risk factors. Indeed, improving human safety depends on reducing the risks that workers are exposed to when carrying out specific work activities taking human factors into consideration (Fagnoli et al., 2018). This means that more attention should be paid to analysing human behaviour (Di Pasquale et al., 2015), and the factors that can affect it, such as stress, training, experience, the relationship with management, etc. (Sadeghi et al., 2015).

Therefore, it is important to know the perception of risk for the different construction tasks or activities in Guatemalan companies. Thus, the Medium risk (not High) perception result for scaffolding and digging tasks is consistent with the results obtained by Hassan et al. (2007) on building workers in Malaysia; since they obtained safety scores for these high tasks both for large and small-scale projects. However, this was not the case for construction workers in Mexico (Solís & Arcudia, 2013), in which one of the main hazards was the use of ladders and scaffolding. As for the 3 construction activities that stand out as having a High-risk probability, are consistent with a study on construction workers in Mexico (Solís & Arcudia, 2013), in which the main hazards identified were: the collapse of structural elements, the use of ladders and scaffolding, electric shocks and working in confined spaces. In a study with construction workers in Spain (Rodríguez-Garzón & López-Alonso, 2013), it was observed that there were statistically significant differences between bricklayers and structural workers, with respect to what the workers thought about the risk knowledge of their work that those responsible for the company have (important risk perception factor), being higher in bricklayers.

Finally, the 6 construction activities highlighted because they are indicated as having “None or Not applicable” risk probability, are hardly carried out by Guatemalan construction companies when compared to the other activities; neither is gas pipeline laying carried out by small-scale Malaysian building companies (Hassan et al., 2007).

### 3.3.2. Multiple correspondence analysis

After performing the multiple correspondence analysis on the studied variables, a two-dimensional mathematical model was obtained, summarising the information from all the analysed variables and presenting good reliability.

From Table 6 and Figures 2 and 3, and despite there being no clear trend for the 5 general company variables, (which present very small discriminations close to the origin of the coordinates), it can be concluded that companies in Cluster 1 are associated to the variables grouped with a Low risk weighting, with a medium to low number of work years, a medium to high number of on-site workers and a medium to low number of office worker with a turnover of more than 100,000 euros. In contrast, those in Cluster 2 are associated with the variables grouped as having a Medium risk weighting, with a high number of

work years, a low number of on-site workers, a medium-to-high number of office workers and a turnover of less than 100,000 euros. The companies in Cluster 3 are only clearly associated with the variables grouped as High risk weighted, and the number of company work years of between 31 and 40 years. Finally, the companies in Cluster 4 are associated with most of the “None or Not applicable” risk-weighting variables, in which no general company variable category is clearly associated. In summary, Clusters 1 and 2 (Low and Medium risk weighting, respectively) are where the largest percentage of analysed companies is concentrated, and this Low risk weighting is a clear indication of minimal accident-risk management and training for company workers, as shown by Rodríguez-Garzón et al. (2014, 2016) furthermore, these companies assume that the worker should know what to do himself/herself to avoid suffering on-site accidents (Aboagye-Nimo et al., 2015).

## Conclusions

A characterization has been carried out on the perception of Guatemalan construction company managers regarding the risk of accidents that their workers might suffer and what accident risks may exist in the different activities performed.

The 3 construction activities carried out by companies that most stand out as having a High-risk probability are: High-voltage power connections and power grids (45.1%), the use of cranes and loading booms (38.4%) and the use of manual, electric or combustion lifts (27.8%).

Using the Multiple Correspondence Analysis technique, it has been concluded that companies are grouped into 4 clusters that have similar characteristics in terms of the accident-risk weighting they present in the particular construction activities performed.

Companies in Cluster 1 are associated to the variables grouped with a Low risk weighting, with a medium to low number of work years, a medium to high number of on-site workers and a medium to low number of office worker with a turnover of more than 100,000 euros. In contrast, those in Cluster 2 are associated with the variables grouped as having a Medium risk weighting, with a high number of work years, a low number of on-site workers, a medium-to-high number of office workers and a turnover of less than 100,000 euros. The companies in Cluster 3 are only clearly associated with the variables grouped as High risk weighted, and the number of company work years of between 31 and 40 years. Finally, the companies in Cluster 4 are associated with most of the “None or Not applicable” risk-weighting variables, in which no general company variable category is clearly associated.

Companies in the Guatemalan construction sector should improve the occupational risk-prevention training of both their managers and workers in order to the accident-risk weighting of the construction activities they carry out were more grounded.

It should be noted that these conclusions obtained from the results of the study are conditioned by the following limitations:

- The study was carried out by surveying the managers of the construction companies in Guatemala and not the workers directly, therefore the data obtained from risk perception, are given from the perspective of the managers, which is interesting as several authors indicate (Wei et al., 2002; Reese & Eidson, 2006).
- In addition, to develop the present study, we considered a sample made up of 5.1% of companies in the current Pre-qualified Companies Census from the Guatemalan Ministry of Communications, Infrastructure and Housing (MICIVI), as of December 2015; therefore, it is an estimate based on the companies in the sample – for other companies, it might be different.

Finally, the following two future research topics are proposed that are related to the present study:

- It would be necessary to propose a new work in which the risk perception measured directly on the workers was analyzed through some of the methods that exist based on psychometric scaling, and thus contrast the results with those obtained from the perspective of the managers.
- Study the economic cost for construction companies in Guatemala of everything related to the prevention of occupational hazards and correlate it with the accidents suffered by these companies.

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## Author contributions

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