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# Occupational Accidents in Ecuador: An Approach from the Construction and Manufacturing Industries

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**Abstract:** Ecuador is a country in South America, where, in 2021, there were 849,874 companies that had total sales of USD 105.23 billion, which had 2,698,650 workers. This study was carried out with the aim of analyzing occupational accidents by industry type in Ecuador, focusing mainly on the construction and manufacturing industries. The data were provided upon express request to the National Directorate of General Occupational Risk Insurance of the Ecuadorian Social Security Institute. The data used in this study concerned accidents involving qualified workers affiliated with the Ecuadorian Social Security System. The data obtained were used to calculate the general accident rate, accident rate by sector, permanent disability rate, and mortality rate. Between 2016 and 2019, 6960 qualifying accidents occurred in Ecuador. Approximately $89.71 \pm 0.36\%$ of the accidents investigated involved men, and $50.28 \pm 2.49\%$ of these accidents caused permanent disability. The mortality rate was, on average, $10.60 \pm 1.83\%$, 2018 being the year with the most deaths due to accidents at work. The Ecuadorian sector with the highest accident rate was the manufacturing industry with $26.15 \pm 2.50\%$, followed by the construction industry with a rate of $17.47 \pm 3.59\%$. The manufacturing industry had the highest rate, with a significant difference of accidents that resulted in permanent disability, with an average of $31.79 \pm 2.85\%$, while the construction sector had the highest rate of fatal accidents, with an average of $25.82 \pm 5.05\%$. This is the first study to report the number of qualified occupational accidents in Ecuador. With this study, a starting point is established for future analyses of the evolution of occupational accidents by type of industry in Ecuador. Future studies could determine the increase or decrease in the number of accidents, evaluate rates of permanent disability and death, and establish risk factors and preventive measures for each task or activity in all productive sectors.

**Keywords:** accident likelihood; accident rate; mortality rate; permanent disability rate; work accidents; productive sector

## 1. Introduction

The economic activity can be divided into several productive sectors. Production sectors establish a classification of the economy based on the type of productive processes that characterizes them. There are three large traditional sectors called primary, secondary or industrial, and tertiary or service sectors, and two additional sectors called quaternary and quinary sectors [1]. Industries are responsible for transforming raw materials into products intended for use by other industries or for personal consumption (direct and indirect). All industries include a lot of labor, as well as machines to help with the process. Industries can be divided according to the purpose of what they produce or the type of activity or sector where they are inserted [2]. One of the types of industry, according to the sector in which they operate, is the construction industry, which is a conglomerate of companies that are responsible for producing a wide range of construction projects

at different scales [3]. The construction industry is considered one of the sectors with the highest employability worldwide, because there is a large number of companies that are dedicated to both construction activities and activities related to it [4,5]. Within the classification of industries by their type of activity is the manufacturing industry. Manufacturing is a key economic activity that can contribute to employment generation, economic growth, technology development, and regional development [6]. Jobs in the manufacturing industry offer opportunities for professional and personal development. The construction and manufacturing industries contribute significantly to the gross domestic product (GDP) of countries; however, as sectors with multiple activities, they report excessive injuries, deaths, and accidents at work [7].

An accident at work is an unexpected event that causes physical or psychological injuries, illnesses, or death [8]. The definition of an occupational accident also includes cases in which workers suffer illnesses or injuries due to their work. These can be occupational diseases that develop over time owing to exposure to toxic or hazardous substances in the workplace or physical injuries that occur at a certain time due to a specific work activity. Accidents are inevitable because of the built-in probability of failure associated with technology and various systems, as well as the innate nature of people to make mistakes by omission or commission, globally [9]. Although accidents occur in all industries, small and medium-sized enterprises (SMEs) generate a deficit in occupational risk management, which can affect both the health and safety of workers, and the productivity and profitability of the organization. In SMEs, human errors and staff turnover trigger occupational accidents due to the lack of adequate protective equipment, poor training in occupational safety, and the lack of safety measures in the workplace [10].

Accidents at work not only have consequences for workers, but also can have a negative impact on companies, since work accidents can result in additional costs for companies, such as employers' liability to a national regulatory body, compensation for affected workers, and loss of productivity due to absenteeism, and in some cases, presenteeism of injured workers [11]. On average, 2.78 million people die each year in work-related accidents and illnesses. In addition, annually, about 374 million men and women suffer injuries and non-fatal illnesses with serious injuries and socioeconomic consequences [9]. Some industries, such as manufacturing or construction, can expose workers to occupational hazards and diseases such as asbestosis, silicosis, or chronic obstructive pulmonary disease (COPD). Worldwide, the statistics show the occurrence of one fatal accident per 10 minutes in the construction industry [12]. According to the United States Occupational Safety and Health Administration (OSHA), 5333 deaths on the job were reported in 2019 [12]. In the European Union, in the construction sector between 2012 and 2018, an average of 382,610 non-fatal accidents occurred, which resulted in at least four calendar days of absence from work, and in the same period, an average of 775 fatal accidents occurred [13]. The OSHA reports that in 2019 there were 885 deaths in the manufacturing industry [12]. In Europe, the manufacturing industry is reported to account for 10% of all fatal accidents at work; 15% of deaths in the manufacturing industry were caused by the use of machinery, and 13% by exposure to hazardous substances [14].

The most common causes of fatal accidents in the construction industry include falls from heights, electrocutions, impacts from objects, and entrapment in machinery [12]. The main risks in manufacturing are injuries owing to contact with objects or machinery, falls, and repetitive motion. The main causes that trigger an accident at work are design failure, pipe or valve faults, equipment failure or damage, electrical damage, improper maneuvering or operation, inadequate safety management, insufficient safety protection measures, and fortuitous events [15]. Human talent is still a critical factor in accidents; most accidents (between 70 and 90%) are due to human error [10]. This implies that despite the advance of technology and automation, people still play a fundamental role in the safety and effectiveness of various activities and processes, which is why it is important to generate greater attention to improving the training and supervision of the people involved.

Ecuador is a country in the South American continent, which is made up of 24 provinces divided into four regions (Coast, Andean, Amazon, and the Galapagos Islands). It has an area of 256,370 km$^2$ and a population of 17.8 million inhabitants. In Ecuador, as of 2021, there are 849,874 companies that have total sales of USD 105.23 billion, and 2,698,650 workers. In nominal terms, Ecuador's gross domestic product (GDP) in 2021 reached USD 106,165.9 million, with manufacturing (12.6%), trade (10.8%) education and social and health services (8.9%), transportation (7.4%), and construction (6.4%) standing out as the main activities [16]. Ecuador is a country known for the export of raw materials derived from natural resources such as oil, mining, and some agricultural products such as bananas, coffee, cocoa, broccoli, and pitajaya, which currently require manufacturing for administration [17]. According to the Ecuadorian Social Security Institute (hereinafter referred to as IESS, for the acronym in Spanish) [18], there were 1305 fatal occupational accidents in the country in 2020. Of these, 102 occurred in the manufacturing industry. This indicates that the manufacturing industry in Ecuador represented a significant proportion of fatal occupational accidents in the country in that year. The construction industry represents around 10% of the total GDP of Ecuador, becoming one of the most important and with the greatest contribution at the national level [19]. The mortality rate due to accidents at work in Ecuador is estimated at 3.5 per 100,000 workers.

It is important to analyze and understand the reasons behind accidents in the safety management and accident prevention process [20]. This stage is essential because it allows us to identify the underlying causes of accidents and to take preventive measures to prevent them from happening again in the future. By understanding the reasons behind accidents, appropriate safety and prevention measures can be implemented to address the underlying causes. The investigation of accidents involves demonstrating what types of accidents occur and how they occur. Fundamentally, accidents are considered to materialize due to three causes: first, a lack of management when unsafe conditions are not identified before starting work; second, continuing with work activity when a latent unsafe condition has been identified; and third, continuing with work activity and minimizing the danger at the workplace [21].

In order to counteract the accident rate, some countries have generated occupational risk prevention audits through control entities [9]. In Ecuador, the Unified Labor System (SUT) allows companies to implement a management system and comply with legal regulations, such as Executive Decree 2393 Regulation on Workers' Safety and Health and Improvement of the Work Environment. In addition to complying with the regulations that apply to the Andean Community (CAN), resolution 957, Andean Instrument for Safety and Health at Work Decision 584, with the appropriate application of the regulations, companies have the possibility of minimizing accidents, occupational diseases or the death of workers.

The prevention of occupational accidents begins with the democratization of reliable data, properly analyzed. These data must be updated and presented in such a way that they serve as a baseline and comparison over time and with other realities (companies and territories), in order to make decisions that benefit workers and companies. However, in Ecuador, there are few published studies on occupational accidents. In 2017, Gómez-García et al. developed a study on the epidemiology of work accidents between 2014 and 2016 [22]. Also in 2017, Ordoñez-Torres et al. performed a quantitative labor risk model for the construction sector [23]. In 2021, Morales et al. carried out a study on occupational accidents in the construction sector in the period 2016–2019 [24]. In 2023, Gomez-Garcia et al. conducted a study on fatal work accidents from 2014 to 2020 [25]. In the same year, Gómez-García analyzed the relationship between the territorial distribution of labor inspectors and work accident injuries [26]. Published studies have focused on reported accidents and do not address industries such as manufacturing or injuries such as permanent disability. In addition, it is necessary to carry out studies with updated data each time.

The analysis of the evolution of occupational accidents constitutes a useful tool for management and decision making. Knowing the sectors with the highest accident rate is important, allowing us to understand the magnitude of the labor safety problem in the country, and it highlights the need to improve workplace safety measures to prevent permanent disability and fatal accidents. These facts, along with the fact that in Ecuador the bibliography on occupational accidents is scarce and not updated, motivated the authors of this study to carry it out with the aim of analyzing the accidents at work that occurred between 2016 and 2021 by type of industry in Ecuador, emphasizing what happened in the construction and manufacturing industries.

It has been deemed appropriate to structure this document into five sections. To begin with, the abstract is presented, in which we give the reader a quick overview of the study. Then, an introduction where, in addition to providing basic information, the aim of the study is established. Third, the Materials and Methods section is presented in the best possible detail to describe the acquisition of data and its treatment. Regarding the results, our findings are shown in graphs and tables, which are compared and examined in the discussion section. Finally, the conclusions of the study are presented.

## 2. Materials and Methods

The scheme in Figure 1 provides an overview of the methodology used and helps us to understand the logical sequence of the steps involved in this study.
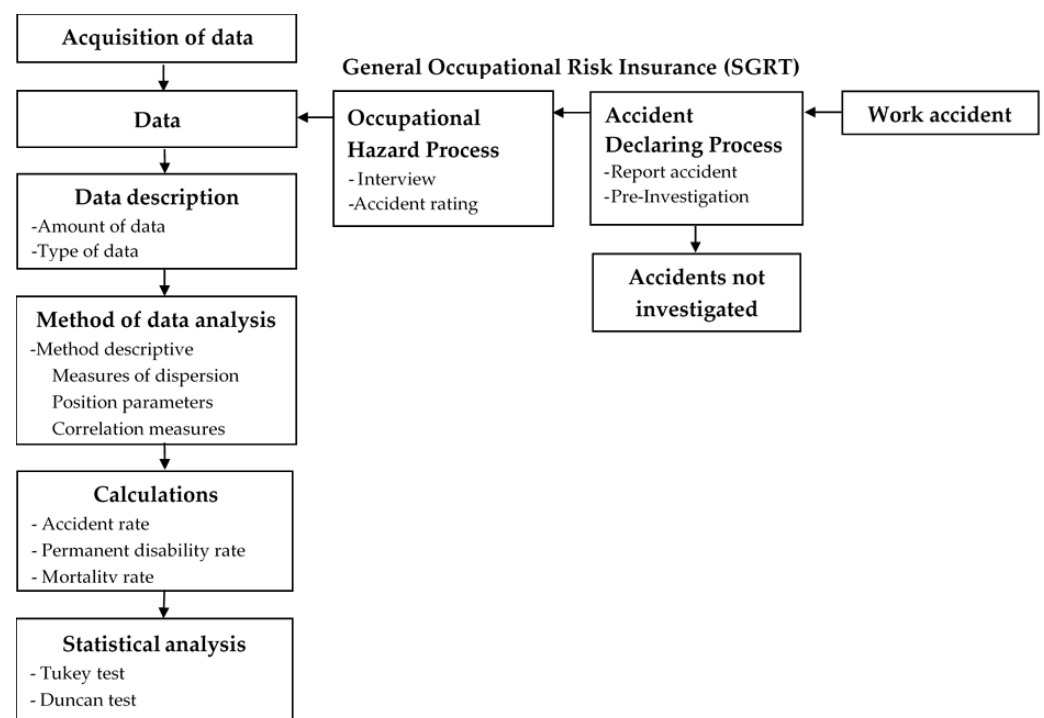


**Figure 1.** Representative scheme of the methodology.

### 2.1. Acquisition of the Data

The data were provided by the General Occupational Risk Insurance (SGRT) of the Ecuadorian Social Security Institute (IESS). The SGRT is the government agency in charge of protecting the insured and employers in contingencies derived from work accidents and occupational diseases [18]. Data were provided after an express request to the national management of this agency. To obtain information for the period 2016–2021, data on accidents in Ecuador during this period were requested. The data provided for this study were from qualified (investigated) accidents. An accident is considered investigated after

it has been subjected to two consecutive procedures: the Accident Declaring Process (reporting) and the Occupational Hazards Process (qualification).

### 2.1.1. Accident Declaring Process

As detailed in resolution C.D. 513., called the Regulation of the General Occupational Risk Insurance of the SGTR, in article 43 Notice Forms, the employer must report an occupational accident within ten days from the date of occurrence through the IESS website [27]. The enabling documents for the qualifying the claim can be submitted at that time. If the employer does not declare the accident at work on time, the regulations empower family members or third parties to report it through the IESS website. Failure to submit enabling documents within the specified period does not exempt the employer from liability. If the employer does not declare the accident within ten days, the labor risk regulatory authority of IESS generates a fine of one unified basic salary in Ecuador, i.e., USD 450 [27].

### 2.1.2. Occupational Hazard Process

Article 46 of the Regulation of the General Occupational Risk Insurance on the qualification of the accident states that when the accident is reported by the employer within 10 days from the date of presentation of the accident, the occupational doctor or the occupational risk technician of IESS may conduct an interview with the worker, the employer's representative and, if required, two witnesses, in order to "expand, complete or clarify the causes or conditions under which the accident occurred". After the accident has been classified, the two criteria are applied to define the accidents to be investigated, as established in the third annex of the C.D. 513 of the General Occupational Risk Insurance Regulations, (a) Accidents classified as typical with fatal consequences or that generate permanent disability; and (b) Accidents that generate temporary incapacity for more than one year". Within the determination of causes, three types of causes that can lead to an accident at work are considered: direct, indirect, and basic. Direct causes define the reason for the occurrence of the accident, considering substandard actions and conditions. Regarding indirect causes, they explain the reason for the direct causes of the accident. While the basic causes override the reason for the indirect causes, failing this allows us to conclude the root cause of the accident [27].

Finally, according to Article 47 of the Regulations of the General Occupational Risk Insurance, an investigation report is generated. The result of the accident investigation is carried out by the IESS risk prevention technician, who will generate a reasoned report, with the technical legal argument. The data presented in this study are those presented in this report.

### 2.2. Data Description

This study is based on information from the SGRT of IESS and covers reports from all over Ecuador. The data on occupational accidents used refer to the number of cases in the categories disaggregated at the national level by type of economic activities, two digits of the National Classification of Economic Activities (CIIU 4.0) [28]. The raw (unanalyzed and unfiltered) data provided contained information on number of workers who have suffered the accident (discrete number), workers' gender (categorical data), nature of the injuries (categorical data), and year in which the accident occurred. The information provided about the workers' accidents was from mishaps that occurred in the workplace, without considering those that occurred on the home–work–home commute. The main advantage of the SGRT database is its reliability since it is the official agency in charge of these data. Another advantage is the disaggregation of the information, which allows disaggregated data to be directly obtained and processed at the national level.

### 2.3. Method of Data Analysis

The data were analyzed using the descriptive method. With this method, the sample data were described by means of characteristic values, which allowed us to present them

in the form of a graph or table. This data presentation refers to the individual variables and their characteristics. Three main measures were used to describe the data: dispersion measures, position parameters, and correlation measures. The purpose of using this method was to synthesize the information to provide precision, simplicity, and to clarify and order the data [29].

*2.4. Calculations*

The general accident rate and the accident rate were calculated by sector, understanding the accident rate as the number of deaths and permanent disabilities caused by accidents at work in a given time expressed as a cumulative frequency [30]. The accident rate has been divided into a separate calculation of the permanent disability rate (the number of people with permanent disability, divided by the total number of people who have suffered an accident), and the calculation of the mortality rate (the number of people who died divided by the total number of people who have suffered an accident).

*2.5. Statistical Analysis*

The data were obtained directly in an Excel spreadsheet format and migrated to Minitab 17 (Version 17.1.0., Minitab LLC., State College, PA, USA) and SPSS (Statistical Package for the Social Sciences, version 25, SPSS Inc., Chicago, IL, USA), as needed. Minitab 17 was used to calculate the measures of central trend. The statistical program SPSS was used to compare the different variables using the Tukey and Duncan test. A $p < 0.0001$ was considered significant. In retrospect comparisons for paired data, it is preferred to use Tukey's HSD (Honestly Significant Difference) test [31]. However, Duncan's test is less conservative than Tukey's test [32], so both tests were applied in this study.

**3. Results**

*3.1. Accident, Disability, and Mortality Rates*

Table 1 shows the overall number of accidents investigated by IESS between 2016 and 2021, with 2017 being the year with the highest number of accidents investigated (1462). The frequency of accidents by gender was 10% on average for women, while for men it was 90% in the years studied. The accidents were grouped into four sections according to their consequences: (i) without consequences or with minor consequences (SC/CL), (ii) serious injury (LG), (iii) permanent disability (IP), and (iv) death (F), where accidents that cause permanent disability in workers occur in greater numbers. The largest number of occupational accidents investigated are in the category of permanent disability.

**Table 1.** Accidents by year, gender, and type of consequence.

| Year | Number of Accidents | Gender | | SC/CL | LG | IP | F |
|------|---------------------|--------|-----|-------|-----|-----|-----|
| | | Women | Men | | | | |
| 2016 | 1189 | 10.43% | 89.57% | 147 | 298 | 608 | 136 |
| 2017 | 1462 | 9.57% | 90.43% | 155 | 498 | 698 | 111 |
| 2018 | 1215 | 10.37% | 89.63% | 129 | 310 | 623 | 153 |
| 2019 | 1301 | 10.37% | 89.63% | 98 | 384 | 694 | 125 |
| 2020 | 853 | 10.55% | 89.45% | 72 | 294 | 399 | 88 |
| 2021 | 940 | 10.43% | 89.57% | 67 | 277 | 483 | 113 |

The rate of permanent disability (IP) resulting from occupational accidents in Ecuador fluctuates between 46.78% and 53.34% from 2016 to 2021, as can be seen in Table 2; likewise, the mortality rate varies between 7.59% and 12.59% in the same period of time.

**Table 2.** Permanent disability and mortality rate.

| Year | Rate IP | Rate F |
|------|---------|--------|
| 2016 | 51.44% | 11.44% |
| 2017 | 47.74% | 7.59% |
| 2018 | 51.28% | 12.59% |
| 2019 | 53.34% | 9.61% |
| 2020 | 46.78% | 10.32% |
| 2021 | 51.38% | 12.02% |

*3.2. Accident Rate, Disability Rate and Mortality Rate by Strategic Sector*

Figure 2 details the accident rate by sector and by year between 2016 and 2021, showing that the economic sectors of construction and manufacturing maintain the highest accident rates compared to other sectors, with an average of 17.47% and 26.15%, respectively, while the rest of the sectors are below 12%.
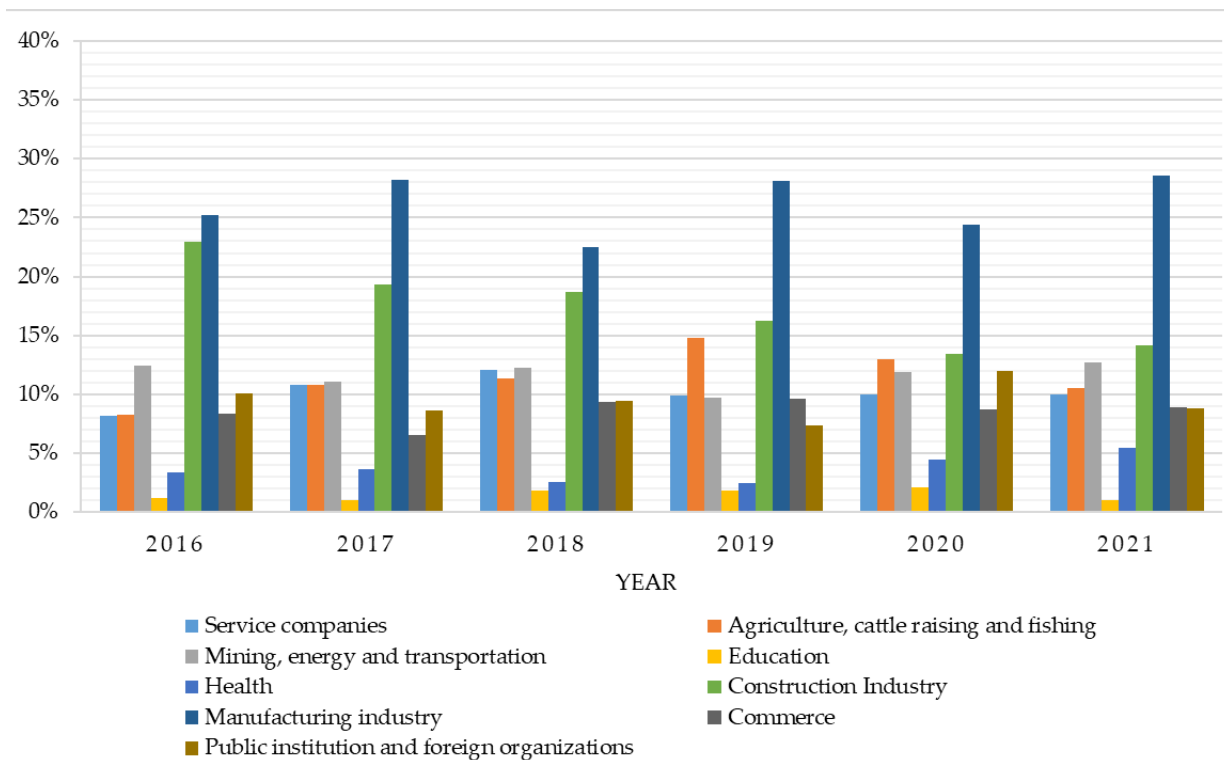


**Figure 2.** Accident rate by sector.

Among the groups by consequence for occupational accidents, permanent disability (IP) and death (F) are the most relevant to be discussed due to their implications for the injured person, their families, and the immediate environment in which they work. Figure 3 shows the evolution of the permanent disability rate by sector, with the manufacturing sector having the highest IP index among the various sectors, reaching a maximum of 35.27% in 2019, and a minimum of 27.97% in 2018. It can also be seen that the construction sector maintains the second highest IP index of the sectors, with an average of 16.66%; however, a slight tendency is observed in this sector.
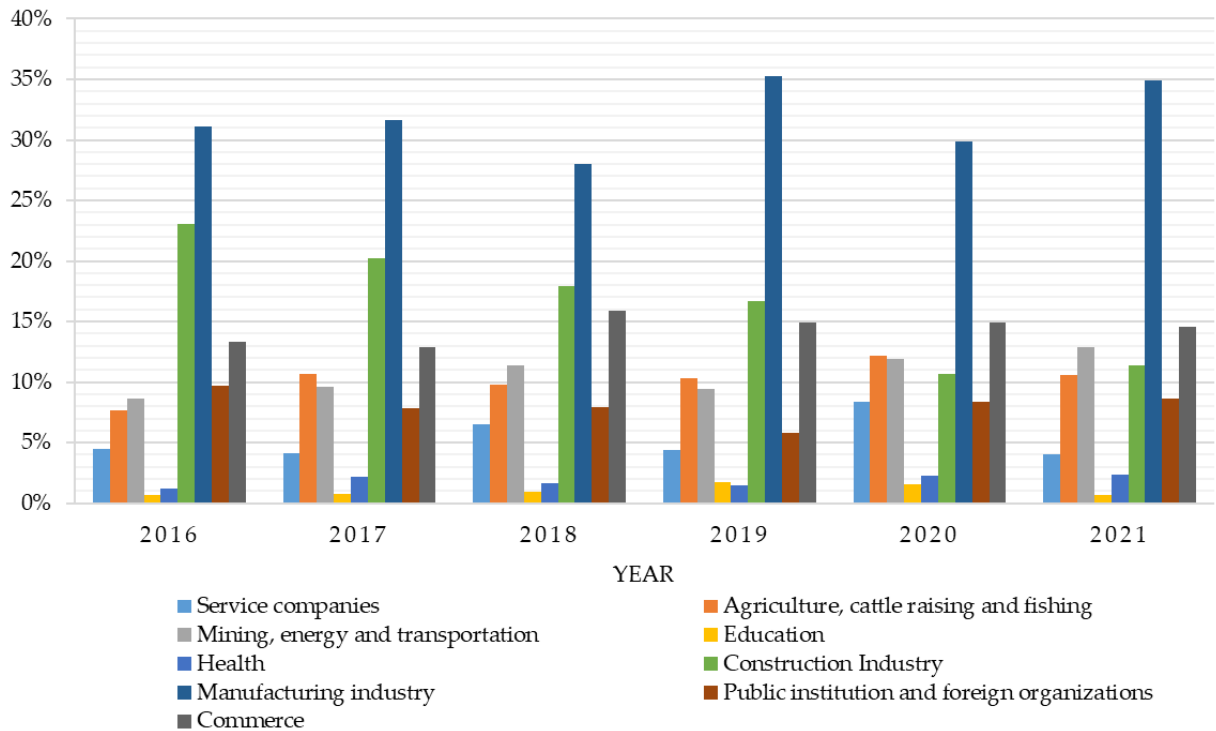
**Figure 3.** Permanent disability rate by sector.

Figure 4 shows the evolution of the death rate (F) by sector in occupational accidents that occurred between 2016 and 2021 in Ecuador, where the construction sector is the most affected of all, with an average rate of 25.82%, having reached a peak of 30.89% in 2019. The Mining, Energy and Transportation sector is in the second place in this index, followed by the sectors of commerce, public service, and manufacturing.
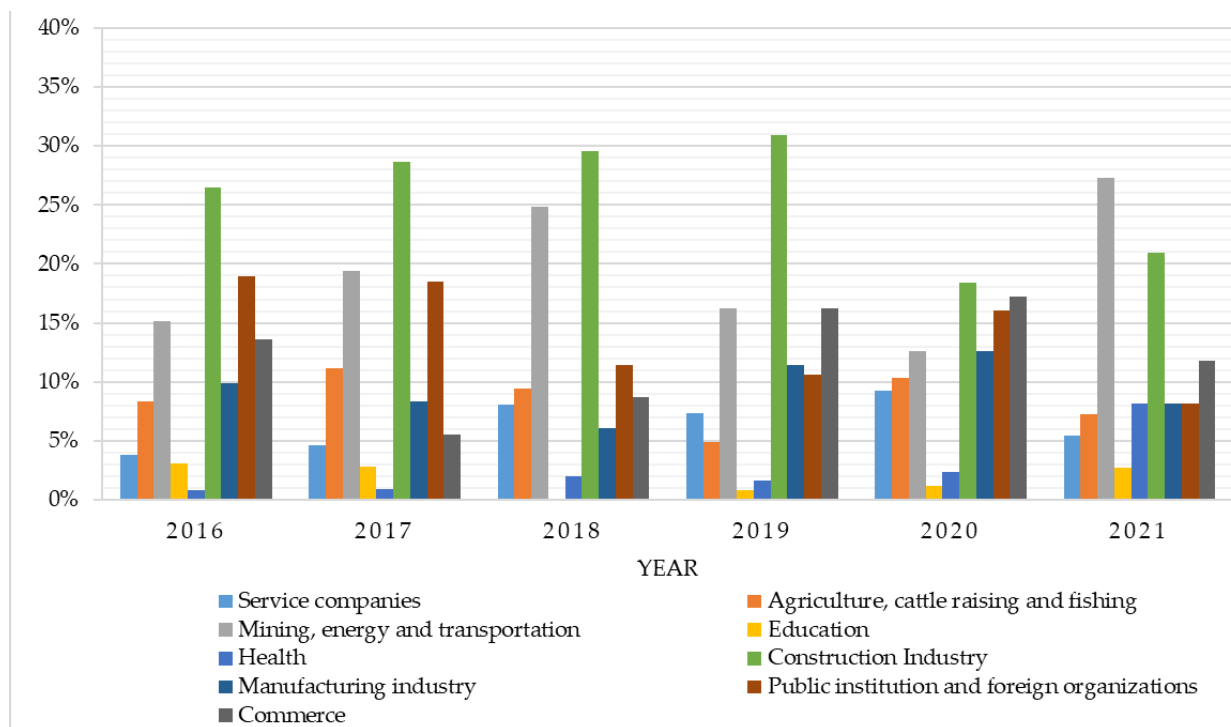


**Figure 4.** Mortality rate by sector.

Table 3 shows the behavior of the variable "disability rate" depending on the sector analyzed. There is evidence of a grouping for the type of sector with a superscript marked by a letter (a–g), where sectors with different letters are significantly different from the others, depending on the permanent disability rate for each, measured with a high level of significance ($p < 0.0001$).

**Table 3.** The effect of the type of sector on the permanent disability rate.

| Sector | Tukey HSD [1] | Duncan [1] |
|---|---|---|
| Education | 6.00 [a] | 6.00 [a] |
| Health | 10.33 [b] | 10.33 [a] |
| Services | 29.33 [b] | 29.33 [b] |
| Public Services and Foreign Organizations | 45.33 [c] | 45.33 [c] |
| Agriculture, livestock, and fishing | 57.50 [c] | 57.50 [c] |
| Mining, Energy, and Transport | 59.67 [d] | 59.67 [d] |
| Commerce | 82.17 [d] | 82.17 [e] |
| Construction | 98.50 [e] | 98.50 [f] |
| Manufacturing | 181.83 [f] | 181.83 [g] |
| *p*-value | <0.0001 | <0.0001 |

[1] Uses harmonic mean sample size = 6.0; Means for groups in homogeneous subsets are displayed. The letters a–g are used to indicate significance.

It can be seen based on both the Tukey and Duncan tests that the manufacturing industry sector is significantly different from all others, with an average higher than all other sectors in its rate of permanent disability resulting from accidents at work in Ecuador. The same occurs in the construction sector, which is significantly different from the rest in terms of the rate of permanent disability due to work accidents, occupying the second highest average of the sectors analyzed.

As with the disability rate, the ANOVA has been carried out for the variable "type of sector" based on the mortality rate derived from accidents at work, an analysis that can be seen in Table 4. This table shows the sectors grouped by a superscript (a–f); those that have different letters are significantly different from the others depending on the permanent mortality rate for these sectors, which is measured with a high level of significance ($p < 0.0001$).

**Table 4.** The effect of the type of sector on the mortality rate.

| Sector | Tukey HSD [1] | Duncan [1] |
|---|---|---|
| Education | 2.00 [a] | 2.00 [a] |
| Health | 3.00 [a] | 3.00 [a] |
| Services | 7.50 [b] | 7.50 [b] |
| Public Services and Foreign Organizations | 16.33 [c] | 16.33 [d] |
| Agriculture, livestock, and fishing | 10.00 [b] | 10.00 [c] |
| Mining, Energy, and Transport | 23.17 [d] | 23.17 [e] |
| Commerce | 14.17 [c] | 14.17 [c] |
| Construction | 31.17 [e] | 31.17 [f] |
| Manufacturing | 10.83 [b] | 10.83 [c] |
| *p*-value | <0.001 | <0.001 |

[1] Uses harmonic mean sample size = 6.0. Means for groups in homogeneous subsets are displayed. The letters a–f are used to indicate significance.

In the Tukey test and the Duncan test, it can be seen that the construction sector is significantly different from all others, with an average higher than all other sectors in terms of its mortality rate due to accidents at work in Ecuador.

## 4. Discussion

The data analyzed in this study are only from the workplace. It is common to think that accidents at work are those that occur only in the workplace. However, it is estimated that these data account for only 68% of the total; the remaining 32% take place outside the workplace; that is, accidents that occur due to work, regardless of the place or time in which they occur. In other words, accidents that occur while workers travel from home to work and vice versa (on their frequent route) are also considered work accidents, representing 10% of total accidents in construction in 2019 [24]. Of all accidents reported in Ecuador, only 5–10% are investigated. In 2016, 20,302 accidents were reported, out of which only 1189 (5.9%) were investigated; in 2017, 15,394 were reported; in 2018, 15,918 were reported, and in 2019, 15,016 accidents were reported [24], out of which 1462, 1215, and 1301 accidents were investigated in the years 2017, 2018, and 2019, respectively, as happened with the present study. In a recent study, it was stated that the number of accidents reported in 2016, 2017, 2018 and 2019 was 19,470, 15,150, 14,490, and 14,530, respectively [26]. In this context, Gómez García et al. report that in 2016 there were 20,296 qualified accidents [22]; although there is a difference in the number of accidents reported between the different studies consulted, the rate of accidents investigated/accidents reported remains between 5–10%.

Between 2016 and 2021, the year with the highest number of accidents was 2017, with 1462 accidents investigated. The increase in accidents investigated does not always correspond to the growth of the productive sector. In 2018, the construction sector grew by 1.1% compared to 2017 [16]; however, there was no growth in the number of accidents. This study is in line with a previous study by Almosabbeh and Almoree, who emphasize that in 2020 and 2021, due to the COVID-19 pandemic, the manufacturing and construction sectors were affected by confinement [6]. In Ecuador, manufacturing decreased by 5.7% compared to 2019, and construction, the most affected sector, decreased by 20%. It decreased by 60% in the first few months [24] of 2020 compared to 2019, and it decreased even more in 2021: 6.6% compared to 2020 [33]. However, reported cases fell by 45% for construction, and 42% for manufacturing in 2020 compared to 2019. This situation can be explained by the direct impact of the pandemic on the workplace, and the types of employment imposed by the new reality, including new schedules and teleworking.

Qualified accidents are mainly caused by men (approximately 90%). According to Gómez García et al., in 2016, in Ecuador, 78.9% of qualified accidents happened to men [22]. In Ecuador, there is a marked difference in the percentage of men and women who work in the different productive sectors. The greatest difference is found in the construction, transport and storage sectors, and mining and quarrying, where only 0.7%, 3.2%, and 4.0% are female workers, respectively. The percentage of women working in the agriculture, livestock, hunting, forestry, and fishing sectors (17.4%); manufacturing industries (17.7%); trade and repair and vehicles (28.4%); education and professional, scientific and technical activities (26.6%); and public administration, defense, social security, and health (23.4%) is lower than the percentage of men, but there is no such marked difference as in the construction sector [34]. Between 2014 and 2019, only 1.4% of the fatal occupational accidents reported in Ecuador happened to women [25]. Between 2016 and 2019, most of the accidents reported (95%) in the construction sector happened to men. Men represent the largest number of those affected in terms of accidents in the construction sector in Ecuador because most workers in this industry are men [24].

The permanent disability rate between 2016 and 2021 averaged 50.33 ± 2.5%, and the mortality rate was 10.60 ± 1.8%. In the period 2014–2019, out of 11,612 reported accidents, 1329 were fatal, equivalent to 1.19% [25]. Accidents that involve death are investigated more frequently than nonfatal accidents. In 2016, 224 fatal accidents were reported, of which 136 (60%) were investigated [35]. According to estimates by the International Labor Organization (ILO), approximately every 90 seconds, a worker dies and 895 suffer accidents as a result of their work, which represents 350,000 deaths and 313 million accidents worldwide each year, with around 30% of these accidents occurring in the construction sector [36]. Personnel linked to the construction industry are three to four times more likely

to die from accidents at work than in other industries, mainly due to the extreme working conditions that workers are exposed to [37]. In a study on fatal accidents in Ecuador between 2014 and 2020, it is stated that during this period, 11,612 cases were reported, out of which 110,275 were non-fatal; out of the 1337 fatal accidents, 368 happened while the worker was traveling home–work–home; out of the remaining 969 cases, only 560 occurred in the workplace, while the other 406 accidents occurred in an unusual place [25]. The difference between the number of fatal accidents that occurred to men and to women is very marked: out of 560 fatal accidents, only 8 happened to women. The months with the most fatal accidents in Ecuador are April (10.6%) and June (10.5%), and the day of the week with the most accidents is Friday (21.38%); as expected, the day with the least fatal accidents is Sunday, with 4.52%. The mean age of deceased workers increases from 38.22 to 44.69 years [25]. In the period 2016–2021, the year with the least fatal accidents was 2020, which could be the result of the confinement suffered due to the COVID-19 pandemic, since the number of workers exposed to risks decreased due to teleworking, which was implemented by many companies.

The Ecuadorian sector with the highest accident rate between 2016–2021 was the manufacturing industry, with 26.15 ± 2.50% (Figure 2), followed by the construction industry with a rate of 17.47 ± 3.59%. In the construction sector, there was an appreciable decrease in the accident rate from 23% in 2016 to 14.12% in 2021. In the case of the manufacturing industry, the rate shows no trend of growth or decline. In Ibero-America, the country with the highest number of accidents in the construction sector is Colombia (28%), followed by Argentina (15%), and Spain (14%). If we consider the percentage of accidents at work based on the total number of workers in each country, the countries with the most accidents in descending order would be Argentina, Colombia, and Portugal [37]. In the years analyzed (2016–2021), the manufacturing industry had the highest rate with a significant difference (Table 3) of accidents that resulted in permanent disability with an average of 31.79 ± 2.85%, reaching a value of 35.27% in 2019. The construction sector was the sector with the highest rate of fatal accidents, with an average of 25.82 ± 5.05%, reaching 30.89% in 2019, with a notable decrease (18.39%) in 2020, a decrease attributed to the lockdown due to the pandemic.

According to ILO estimates, every year around 317 million people are victims of accidents at work around the world, and 2.34 million people die due to accidents or occupational diseases. In the Americas, the available figures indicate that there are 11.1 fatal accidents per 100,000 workers in the industry (this being the highest value, which is consistent with the present study), 10.7 in agriculture, and 6.9 in the service sector. Some of the most important sectors for the region's economies, such as mining, construction, agriculture, and fishing, are also among those with the highest incidence of accidents [36]. It cannot be overlooked that construction is one of the industries with the greatest influence on the progress and financial growth of nations around the world owing to the strong impact of the industry in other sectors with a predominance in the economy, mainly as a result of the close relationship between infrastructure and development [38,39]. Based on this financial influence, it is notable that that construction provides a great welcome to workers with little or no specialization, helping to reduce unemployment with low investment by eliminating training costs. However, the positive factors mentioned are contradictory, since they also promote occupational informality and, in turn, accidents, affecting the productivity, quality, and reputation of companies, resulting in an additional public health problems and, at the same time, a waste of public and private money. In Europe, in turn, only considering working hours lost owing to accidents at work, 2.6% or more of the gross domestic product (GDP) is lost annually. Globally, the economic costs for countries regarding occupational injuries, including work-related illnesses, range from 1.6% to 6.0% of the total national GDP [37].

Although the construction industry is not the one with the highest number of accidents in Ecuador, it is the one with the highest mortality in its accidents. The construction activity in 2020 decreased by 60%, in the first few months, compared to 2019, but this was one of

the first sectors to have a pilot plan for the COVID-19 health emergency; thus, the National Risk Management Service (COE) authorized the resumption of construction activities from 21 April 2020, and by the months of June and July, several workplaces had resumed their activities, which translated into an increase in the labor force, but gradually; hence, the year 2020 is considered atypical for the statistical analysis of accidents in Ecuador. Construction is the second most frequent activity in the country with the highest number of accidents. It should be considered that the number of accidents in construction may be much higher, since there are people who perform activities in this sector informally, becoming part of the informal sector of the country's labor economy, as the workers are not insured. It is estimated that 50% to 70% (depending on the source consulted) [40,41] of the country's economically active population works informally; that is, they have no social insurance, and only employers, affected members, or their families can report accidents.

## 5. Conclusions

In Ecuador, there have been few studies on occupational accidents. This is the first study to report the number of qualified occupational accidents in Ecuador. The main contribution of this study is focused on promoting the development of prevention strategies to reduce mortality from accidents in the Ecuadorian population, based on the findings found in the accident data investigated in this country. In Latin American countries, it is very difficult to record 100% of accidents and deaths, due to the informality and series of procedures to record the accident, which lead to certain inaccuracies in the data management. The fact of non-compliance with safety regulations in buildings is also highlighted, being more evident in small workplaces, where cases are not reported, as they are resolved directly, which is why national and international safety and health regulations should also be shared with workers, and short training and safety courses for workers should be designed.

In addition to the human cost of diseases and accidents, it must be considered that they affect production and economic performance and generate significant medical expenses. The construction and manufacturing industries are the two most dangerous sectors, mainly because of the operation of machinery, work at heights, and the uncomfortable work positions in which those workers perform different activities. The results show that these two sectors have the highest number of accidents and the highest rates of permanent disability and death. For this reason, it is important to constantly evaluate the risk factors present in the construction and manufacturing industries to periodically quantify the levels of risk and to be able to effectively intervene.

Prevention is key to improving health and safety at work, and the importance of ensuring that strategies to prevent accidents and illnesses at work are reinforced with social dialogue involving governments, employers' and workers' organizations is raised. It is important that the countries of Latin America and the Caribbean have an adequate regulatory framework, that they have national policies and programs for health and safety at work, and that they promote the coordinated action of the different entities dealing with these issues. It is also proposed that the existence of an effective inspection system to ensure compliance with the standard is key. Another aspect that is considered essential is that of having better systems for recording and reporting accidents at work and occupational diseases, since adequate information is essential to establish priorities and improve the design of prevention strategies.

In this study, the authors establish a starting point for future analyses of the evolution of occupational accidents by the type of industry in Ecuador. An expansion of this study is recommended to establish risk factors and preventive measures for each task in activities in all productive sectors, due to its limitations which originate from the acquisition of data, as currently only between 5% and 10% of cases in Ecuador are investigated. The democratization of these results can help generate public policies that allow accidents to be minimized for the benefit of workers' health and the economy of the industrial sector.

Future studies should be conducted to continue examining the increase or decrease in the number of accidents, and the rates of permanent disability and death.

## References

1. Jing, C.; Su, B.; Zhai, J.; Wang, Y.; Lin, Q.; Gao, M.; Jiang, S.; Chen, Z.; Jiang, T. Gridded value-added of primary, secondary and tertiary industries in China under Shard Socioeconomic Pathways. *Sci. Data* **2022**, *9*, 309. [CrossRef]
2. Phillips, R.L.; Ormsby, R. Industry classification schemes: An analysis and review. *J. Bus. Financ. Librariansh.* **2016**, *21*, 1–25. [CrossRef]
3. Feng, Q.; Wang, K.; Feng, Y.; Shi, X.; Rao, Y.; Wei, J. Incentives for Promoting Safety in the Chinese Construction Industry. *Buildings* **2023**, *13*, 1446. [CrossRef]
4. Shaheen, S.M.; Antoniadis, V.; Shahid, M.; Yang, Y.; Abdelrahman, H.; Zhang, T.; Hassan, N.E.E.; Bibi, I.; Niazi, N.K.; Younis, S.A.; et al. Sustainable applications of rice feedstock in agro-environmental and construction sectors: A global perspective. *Renew. Sustain. Energy Rev.* **2022**, *153*, 111791. [CrossRef]
5. Alaloul, W.S.; Musarat, M.A.; Rabbani, M.B.; Iqbal, Q.; Maqsoom, A.; Farooq, W. Construction Sector Contribution to Economic Stability: Malaysian GDP Distribution. *Sustainability* **2021**, *13*, 5012. [CrossRef]
6. Almosabbeh, I.A.; Almoree, M.A. The relationship between manufacturing production and economic growth in the Kingdom of Saudi Arabia. *J. Econ. Stud.* **2018**, *45*, 674–690. [CrossRef]
7. Khahro, S.H.; Ali, T.H.; Memon, N.A.; Memon, Z.A. Occupational accidents: A comparative study of construction and manufacturing industries. *Curr. Sci.* **2020**, *118*, 243. [CrossRef]
8. Mutlu, N.G.; Altuntas, S. Assessment of occupational risks In Turkish manufacturing systems with data-driven models. *J. Manuf. Syst.* **2019**, *53*, 169–182. [CrossRef]
9. Behera, R.K.; Hassan, M.I. Regulatory interventions and industrial accidents: A case from India for 'Vision Zero' goals. *Saf. Sci.* **2019**, *113*, 415–424. [CrossRef]
10. La Fata, C.M.; Adelfio, L.; Micale, R.; La Scalia, G. Human error contribution to accidents in the manufacturing sector: A structured approach to evaluate the interdependence among performance shaping factors. *Saf. Sci.* **2023**, *161*, 106067. [CrossRef]
11. Gavious, A.; Mizrahi, S.; Shani, Y.; Minchuk, Y. The costs of industrial accidents for the organization: Developing methods and tools for evaluation and cost–benefit analysis of investment in safety. *J. Loss Prev. Process Ind.* **2009**, *22*, 434–438. [CrossRef]
12. van Heerden, J.H.F.; Musonda, I.; Okoro, C.S. Health and safety implementation motivators in the South African construction industry. *Cogent Eng.* **2018**, *5*, 1446253. [CrossRef]
13. Mitrevska, C.; Mitrevska, E.; Mitrevski, V. Statistical indicators for accidents at work in construction sector. *Ann. Fac. Eng. Hunedoara—Int. J. Eng.* **2022**, *20*, 87–90.
14. Ivascu, L.; Cioca, L.-I. Occupational Accidents Assessment by Field of Activity and Investigation Model for Prevention and Control. *Safety* **2019**, *5*, 12. [CrossRef]
15. Xiang, Y.; Wang, Z.; Zhang, C.; Chen, X.; Long, E. Statistical analyasis of major industrial accidents in China from 2000 to 2020. *Eng. Fail. Anal.* **2022**, *141*, 106632. [CrossRef]
16. Banco Central del Ecuador. La Economía Ecuatoriana Creció 1.3% en 2018. Available online: https://www.bce.fin.ec/boletines-de-prensa-archivo/la-economia-ecuatoriana-crecio-13-en-2018 (accessed on 16 January 2023).
17. Zapata Chin, K.P.; Nieves Nieves, W.J.; Vega Granda, A.d.C. Manufactura y Crecimiento Económico en Ecuador, 1990–2019: Validez de la primera ley de Kaldor. *Rev. Metrop. Cienc. Apl.* **2022**, *5*, 169–178.
18. Instituto Ecuatoriano De Seguridad Social (IESS). Estadísticas del Seguro de Riegos del Trabajo. Available online: https://sart.iess.gob.ec/SRGP/indicadores_ecuador.php (accessed on 17 January 2023).
19. Camino-Mogro, S.; Bermudez-Barrezueta, N. Productivity determinants in the construction sector in emerging country: New evidence from Ecuadorian firms. *Rev. Dev. Econ.* **2021**, *25*, 2391–2413. [CrossRef]

20. Persona, A.; Battini, D.; Faccio, M.; Bevilacqua, M.; Ciarapica, F.E. Classification of occupational injury cases using the regression tree approach. *Int. J. Reliab. Qual. Saf. Eng.* **2006**, *13*, 171–191. [CrossRef]

21. Abdelhamid Tariq, S.; Everett John, G. Identifying Root Causes of Construction Accidents. *J. Constr. Eng. Manag.* **2000**, *126*, 52–60. [CrossRef]

22. Gómez-García, A.R.; Merino Salazar, P.; Tapia Claudio, O.M.; Espinoza Samaniego, C.E.; Echeverría López, M.A. Epidemiology of occupational accidents in Ecuador based on the Social Security database in 2014–2016. *SCientifica* **2017**, *15*, 14–18.

23. Ordoñez-Torres, M.A.; Garcés-Coca, E.A.; Martínez-Villacrés, H.D. Quantitative labor risk model for the construction sector in Ecuador. *Polo Conoc.* **2017**, *2*, 890–920. [CrossRef]

24. Morales, K.; Pacheco, G.; Viera, L.P. Work accident in the construction sector: Ecuador, period 2016–2019. *INGENIO* **2021**, *4*, 35–45. [CrossRef]

25. Gómez-García, A.R.; Córdova Falconí, K.P.; Merino-Salazar, P.; García-Arroyo, J. Fatal work accidents in Ecuador from 2014 to 2020: How the age of the deceased worker relates to the accidents' temporal and geographical characteristics. *Arch. Environ. Occup. Health* **2023**, *78*, 305–311. [CrossRef] [PubMed]

26. Gómez-García, A.R.; Vega Chica, M.L.; García-Arroyo, J.A. Relationship between the territorial distribution of labor inspectors and work accident injuries: Clustering Ecuadorian provinces into four management scenarios. *Saf. Sci.* **2023**, *158*, 105956. [CrossRef]

27. Consejo Directivo del Instituto Ecuatoriano de Seguridad Social. Resolución No. C.D. 513. Reglamento del Seguro General de Riesgos del Trabajo. 2016. Available online: https://www.iess.gob.ec/documents/10162/33703/C.D.+513 (accessed on 7 February 2023).

28. Instituto Nacional de Estadística y Censos (INEC). Unidad de Análisis de Síntesis. Clasificación Nacional de Actividades Económicas. Available online: https://aplicaciones2.ecuadorencifras.gob.ec/SIN/metodologias/CIIU%204.0.pdf (accessed on 15 February 2023).

29. Mishra, P.; Pandey, C.M.; Singh, U.; Keshri, A.; Sabaretnam, M. Selection of appropriate statistical methods for data analysis. *Ann. Card. Anaesth.* **2019**, *22*, 297–301. [CrossRef] [PubMed]

30. Instituto de Salud Pública de Chile. Guía de Conceptos Básicos e Indicadores en Seguridad y Salud en el Trabajo. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwji9ILUmc2 AAxXt_rsIHTmzAekQFnoECBAQAQ&url=https%3A%2F%2Fwww.ispch.cl%2Fwp-content%2Fuploads%2F2023%2F03% 2FGuia-Conceptos-Basicos-e-Indicadores-en-SST_v2-2023.pdf&usg=AOvVaw0RTjOCNBsKPFKcWtyWQKXy&opi=89978449 (accessed on 27 February 2023).

31. Dagnino, S.J. Comparaciones múltiples. *Rev. Chil. Anest.* **2014**, *43*, 311–312.

32. García Villalpando, J.A.; Castillo Morales, A.; Ramírez Guzmán, M.E.; Rendón Sánchez, G.; Larqué Saavedra, M.U. A comparison of tukey duncan dunnett Hsu and bechhofer procedures for selection of means. *Agrociencia* **2001**, *35*, 79–86.

33. Banco Central del Ecuador. Informe de la Evolución de la Economía Ecuatoriana en 2022 y Perspectivas 2023. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiM0eHjmc2AAxW8gf0HHT_ zDXAQFnoECB0QAQ&url=https%3A%2F%2Fcontenido.bce.fin.ec%2Fdocumentos%2FAdministracion%2FEvolEconEcu_2022 pers2023.pdf&usg=AOvVaw0x_EYl6Nf_fblfgPDu5AZE&opi=89978449 (accessed on 28 February 2023).

34. Consejo Nacional para la Igualdad de Género Gobierno de la republica del Ecuador. *Mujeres y Hombres en Cifras IV: Una Mirada Estratégica Desde el Género y las Diversidades*; Digital Center: Quito, Ecuador, 2021; p. 297.

35. Vilaret Serpa, A.; Silva Peñaherrera, G.M.; Merino Salazar, P.; Suasnavas Bermudez, P.R.; Gómez García, A.R. Temporal and spatial distribution fatal occupational injuries in Ecuador. *INNOVA Res. J.* **2017**, *2*, 175–186.

36. International Labour Organization (ILO). Occupational Safety and Health in the Americas. Available online: https://www.ilo. org/global/topics/safety-and-health-at-work/country-profiles/americas/lang{-}{-}en/index.htm (accessed on 6 March 2023).

37. Hernández, J.; Neves dos Santos, J. Análisis y clasificación iberoamericana de la accidentalidad laboral en la industria de la construcción civil. *Rev. Ing. Constr.* **2020**, *35*, 135–147. [CrossRef]

38. Alfadil, M.O.; Kassem, M.A.; Ali, K.N.; Alaghbari, W. Construction Industry from Perspective of Force Majeure and Environmental Risk Compared to the COVID-19 Outbreak: A Systematic Literature Review. *Sustainability* **2022**, *14*, 1135. [CrossRef]

39. Martínez Rebollar, A.; Campos Francisco, W. The Correlation Among Social Interaction Activities Registered Through New Technologies and Elderly's Social Isolation Level. *Rev. Mex. Ing. Biomed.* **2015**, *36*, 181–191. [CrossRef]

40. Arias Marín, K.; Carrillo Maldonado, P.; Torres Olmedo, J. *Análisis del Sector Informal y Discusiones Sobre la Regulación del Trabajo en Plataformas Digitales en el Ecuador*; United Nations, Economic Commission for Latin America and the Caribbean (ECLAC): Santiago de Chile, Chile, 2020.

41. Llerena, A. Análisis del Mercado Laboral Ecuatoriano: Panoramas y Desafíos. Available online: https://ccq.ec/analisis-del-mercado-laboral-ecuatoriano-panoramas-y-desafios/ (accessed on 23 February 2023).