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Evaluation of the Occupational Health and Safety System in Construction Activity in Peru

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This study evaluates the occupational health and safety (OSH) system of the construction sector in Peru for eight years (2016-2023), based on the analysis of data reported to the Ministry of Labor and Employment Promotion - MTPE, which are accident notifications in construction activities in the 25 regions of Peru, whose activities are five of the same ones that are identified according to the International Standard Industrial Classification – ISIC, which made it possible to identify trends and critical disparities. The findings reveal that the Construction of Complete Buildings or Parts of Buildings activity is high risk because it recorded the highest number of accidents, with 25,244 incidents. Regional disparities Lima, Arequipa and Ucayali, had the highest number of construction accidents, indicating the need for specific safety interventions. Statistically, the ANOVA results showed significant differences in the number of accidents recorded between the five construction activities (F-statistic: 2.75, p-value: 0.031; showing strong correlations and high positive correlations (0.84 to 1.00) between the number of accidents from the five construction activities and the 25 regions, they identify a constant high risk. These findings highlight the need for improved safety standards, specific training, periodic safety audits and data-driven policies to improve safety. in the different workplaces of the construction industry in Peru. This research provides a basis for specific interventions to reduce accidents and protect workers.

Keywords: Occupational health and safety (OHS), Construction accident, ISIC Codes, Peru, Statistical Analysis.

1. Introduction

Construction activity is one of the most important in many parts of the world and plays an essential role in the progress of a country [1][2]. Globally, construction is one of the most critical and dangerous industries [3][4]. The tripartite constituents of the ILO are very concerned about the number of occupational accidents suffered by construction workers, earnest and fatal ones [5][6][7]. In developed nations, construction workers are 3 to 4 times more likely than other types of workers to be involved in fatal workplace accidents. Cumulative exposure to hazardous substances causes many more health problems and occupational deaths.

More than 395 million workers worldwide suffered non-fatal work-related injuries in 2019, according to the latest estimates by the ILO covering the year 2019. In addition, work-related factors caused the deaths of around 2.93 million workers, an increase of more than 12 per cent compared to 2000 [8]. Ensuring the safety and health of workers in this sector is paramount [9][10], as is their training and communication to obtain better education in health and safety in construction activity in general.[11].

The International Labor Organization (ILO) published the "ILO-OSH Guidelines for the Management of Occupational Safety and Health 2001" in response to the increasing incidence of injuries and illnesses in the workplace, recalling that "The protection of workers against work-related illnesses, diseases and accidents is part of the historic mandate of the ILO. Illnesses and incidents should not be associated with the job, nor can poverty justify ignoring the safety and health of workers" [12]. Therefore, this document serves as a guide for nations that wish to voluntarily apply these guidelines and manage safety and health at the national level[13].

Peru is no stranger to presenting the world's problems regarding the safety and health of workers, according to the Computerized Notification System for Work Accidents, Dangerous Incidents and Occupational Illnesses. In recent years, fatal accidents have been reported in different regions of the country due to the lack of implementation of occupational health and safety management of personnel [14].

The Safety and Health at Work Regulations for the Construction Sector in Peru was approved by Decree Supreme D.S. 011-2019-TR in 2019 [15], establishing a Sector Standard for the construction industry. In 2012, the D.S. 005-2012-TR [16] Regulations of Law 29783 provided guidelines for compliance with the Law of Safety and Health at Work, serving as a reference for its implementation, used in the OHSAS 18001:2007 [17] and ISO 45001:2018 [18] model management systems to establish the implementation guidelines of a national management system.

The construction sector is vital to Peru's economy, contributing significantly to infrastructure development and employment [19][20]. However, construction activity in Lima and other regions of Peru is also one of the most dangerous industries, with a high incidence of accidents and work-related injuries [21][13].

This study's general objective is to evaluate the effectiveness of the occupational safety and health (OSH) system in the construction sector of Peru during the eight years between 2016 and 2023. For the study, the data comes from notifications of work accidents by region of the construction economic activity reported to the Ministry of Labor and Employment Promotion; the 05 classes are identified according to the International Standard Industrial Classification – ISIC [22], and the respective ISIC codes below: Land Preparation (Construction) 45100, Construction of Complete Buildings or Parts of Buildings 45201, Building Conditioning 45301, Building Completion 45400 and Rental of Construction and Demolition Equipment with Operators 45500.

The specific objectives of this research are:

1. Identify High-Risk construction activities: To determine which categories of construction activities, classified by ISIC codes, have the highest number of reported accidents.

2. Analyze Regional Disparities: To assess the distribution of construction accidents across different regions in Peru and identify regions with the highest and lowest accident rates.

3. Evaluate Temporal Trends: To analyze the trends in construction accidents over the eight years to understand whether the number of accidents is increasing, decreasing, or stable.

4. Determine Statistical Significance of Differences: To perform an ANOVA test to identify if there are statistically significant differences in the number of accidents among various ISIC codes.

5. Assess Correlation Between Regions and Construction Activities: To analyze the correlation between accident numbers in different regions and ISIC codes to identify consistent patterns of high-risk areas.

6. Provide Recommendations for OHS Improvements: To develop actionable recommendations for improving the OHS system based on the identified high-risk regions and activities.

2. MATERIALS AND METHODS

2.1. Study Area

Geographic and Socioeconomic Context

Researchers conducted the study in Peru, a country in western South America bordered by Ecuador, Colombia, Brazil, Bolivia, Chile, and the Pacific Ocean. Peru is geographically diverse, with coastal regions, highlands, and the Amazon rainforest influencing its economic activities and construction industry.

Peru's construction sector is a vital component of its economy, contributing significantly to its GDP and providing employment to a substantial portion of the population. The sector is involved in various activities, including residential, commercial, and infrastructure projects, essential for the country's development. The rapid urbanization and infrastructure development have led to increased construction activities, particularly in major urban centres such as Lima, Arequipa, and Ucayali.

Occupational Health and Safety in Peru

National regulations and standards in Peru govern occupational health and safety (OHS) to protect workers across various industries, including construction. The Ministry of Labor and Employment Promotion (Ministerio de Trabajo y Promoción del Empleo, MTPE) is the primary authority responsible for implementing and enforcing OHS regulations. Despite these regulations, the construction industry in Peru faces significant challenges in ensuring worker safety due to various factors such as inadequate enforcement, limited resources, and varying levels of compliance across regions.

Regional Focus

The study analyses construction accidents in 25 regions, considering 24 departments and the Constitutional Province of Callao over eight years (2016-2023). The regions included in the study are:

Lima: The capital and largest city, Lima is Peru's economic and industrial hub, with extensive construction activities.

Arequipa: The second most populous city, known for its industrial and commercial significance.

Ucayali: A region in the Amazon basin experiencing growth in infrastructure projects.

Ancash, Apurimac, Ayacucho, Cajamarca, Callao, Cusco, Huancavelica, Huanuco, Ica, Junin, La Libertad, Lambayeque, Loreto, Madre de Dios, Moquegua, Pasco, Piura, Puno, San Martin, Tacna, Tumbes: These regions represent a mix of urban and rural areas with varying levels of construction activity.

The study leverages data categorized by International Standard Industrial Classification (ISIC) codes to comprehensively evaluate OHS in the construction sector across these diverse regions.

2.2. Methodology

Data Collection

The study used a complete data set of construction accidents in Peru from 2016 to 2023. The Ministry of Labor and Employment Promotion (MTPE) obtained the data from work accident notifications, available at the following link: https://www2.trabajo.gob.pe/estadisticas/estadistica-de-accidentes-por-activity-economica/, where there is a large number of variables study of the economic activities carried out in Peru such as agriculture, livestock, hunting and forestry; Fishing; Exploitation of mines and quarries; Manufacturing industries; Supply of electricity, gas and water; Construction; Wholesale and retail trade in motor vehicle repair; transportation, storage and communications; financial intermediation; real estate, business and rental activities, among other activities, selected only the construction activity corresponding to division 45 that considers the five subclassifications, identified according to the International Standard Industrial Classification – ISIC [22], and the respective ISIC codes, shown in Table 1.

Table 1. Economic activities of construction corresponding to division 45 of the International Standard Industrial Classification - ISIC

N°	ISIC	Code ISIC
1	Land Preparation (Construction)	45100
2	Construction of Complete Buildings or Parts of Buildings	45201
3	Building Conditioning	45301
4	Building Completion	45400
5	Rental of Construction and Demolition Equipment with Operators	45500

The dataset includes detailed records of construction accidents, categorized by year, region, and ISIC (International Standard Industrial Classification) codes. Each record provides information on the number of reported accidents related to specific construction activities in various areas across Peru.

Data Preparation

Data Cleaning: We examined the data set for inconsistencies or missing values. Since dashed records represent unreported values, we replaced them with a value of 0 to ensure the accuracy and reliability of the analysis.

Data Transformation: We transformed the data into a structured format suitable for statistical analysis. This process involved categorizing the 05 accident records by ISIC codes and the 25 annual accident regions to facilitate trend analysis.

Statistical Analysis

We conducted several statistical analyses to evaluate the occupational health and safety system in Peru's construction sector:

1. Summary Statistics:

Objective: Provide an overview of the total number of construction accidents by ISIC code and region.

Method: Calculate the sum of accidents for each ISIC code and each region during the eight years.

2. Trend analysis:

Objective: Analyze the trends in construction accidents for the principal ISIC codes with the highest number of accidents in all regions.

Method: We used line charts to visualize the annual accidents for specific ISIC codes and identify significant patterns or changes over time.

3. ANOVA Test (Analysis of Variance):

Objective: Determine if there are statistically significant differences in the number of construction accidents between different ISIC codes.

Method: We performed a one-way ANOVA test to compare the average number of accidents in various ISIC codes. The test identifies whether the observed differences in the number of accidents are statistically significant.

Statistical software: We used the SciPy Python library for the ANOVA test.

4. Correlation analysis:

Objective: To evaluate the correlation between the number of accidents in different regions and ISIC codes and identify consistent patterns of high-risk areas.

Method: Pearson correlation coefficients were calculated between the number of accidents in different ISIC codes and regions to determine the strength and direction of the relationships.

5. Display:

Objective: Effectively communicate findings through visual representations.

Method: We used bar graphs and line diagrams to visualize the distribution of accidents across regions, ISIC codes, a

nd trends over time.

3. RESULTS AND DISCUSSION

Step 1: Summary Statistics

Table 2 presents the results of the evaluation and analysis of the 26,948 records of work accident notifications in Peru's construction activity from 2016 to 2023, including the total number of accidents with their respective ISIC codes. Table 3 shows the total number of accidents by region.

Table 2. Total accidents reported per construction activities associated with each ISIC Code from 2016 to 2023.

N°	ISIC Code	Classes of construction economic activity by ISIC	Total Accidents
1	45100	Land Preparation (Construction)	145
2	45201	Construction of Complete Buildings or Parts of Buildings	25244
3	45301	Building Conditioning	1126
4	45400	Building Completion	369
5	45500	Rental of Construction and Demolition Equipment with Operators	64
		Total	26948

Table 2 provides the total number of accidents associated with each ISIC code. This data allows us to identify which categories of construction work have the highest and lowest accident numbers. The activity that has the highest number of accidents is the construction of complete buildings or parts of buildings, with 25,244 accidents, followed by the activity of Building Conditioning, with 1,126 accidents, and the activity with the lowest number of accidents is the Rental of Construction and Demolition Equipment with Operators 64 accidents.

Table 3. Total accidents reported in construction activity per region from 2016 to 2023.

N°	Region	Total Accidents
1	Amazonas	2
2	Ancash	326
3	Apurimac	3
4	Arequipa	1985
5	Ayacucho	38
6	Cajamarca	231
7	Callao	687
8	Cusco	32
9	Huancavelica	46
10	Huánuco	74
11	Ica	63
12	Junín	141
13	La Libertad	434

14	Lambayeque	122
15	Lima	18975
16	Loreto	193
17	Madre De Dios	10
18	Moquegua	256
19	Pasco	168
20	Piura	976
21	Puno	34
22	San Martin	69
23	Tacna	185
24	Tumbes	5
25	Ucayali	1893
	Total	26948

Table 3 presents the 26948 accident records in construction activity by region, identifying that the five regions with the highest total number of accidents were Lima with 18975 accidents, Arequipa with 1985 accidents, Ucayali with 1893 accidents, Piura with 976 accidents and Callao with 687. accidents. The five regions with the lowest total number of construction accidents are Amazonas with two accidents, Apurímac with three accidents, Tumbes with five accidents, Madre de Dios with ten accidents, and Cusco with 32 accidents.

Step 2: Trend Analysis

For trend analyses of the evolution of the number of accidents reported by each construction activity over the years, Fig. 1 presents the data, including the construction activity "Land Preparation" associated with ISIC code 45100, Fig. 2 with the activity Construction of Complete Buildings or Parts of Buildings associated with ISIS code 45201, Fig. 3 with the activity Building Conditioning associated with ISIS code 45301, Fig. 4 with the activity Building Completion associated with ISIS code 45400 and Fig. 5 with the activity Rental of Construction and Demolition Equipment with Operators associated with ISIS code 45500.

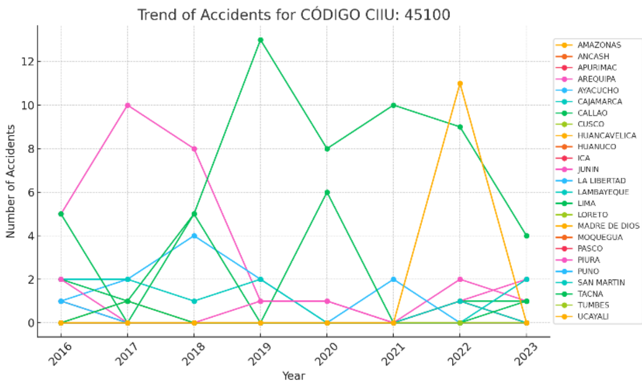

Fig. 1. Trend analysis for the land preparation activity from 2016 to 2023

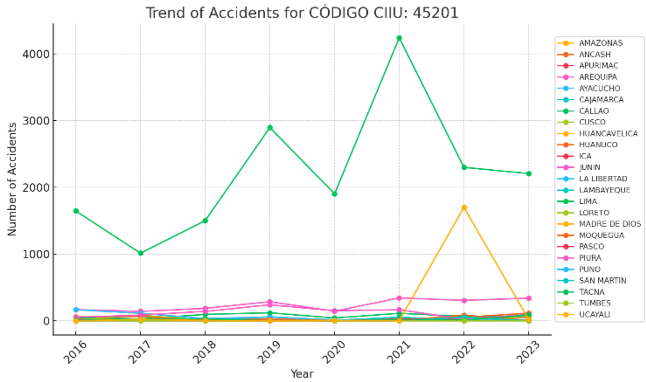

Fig. 2. Trend analysis for the construction of complete buildings or parts of buildings activity from 2016 to 2023

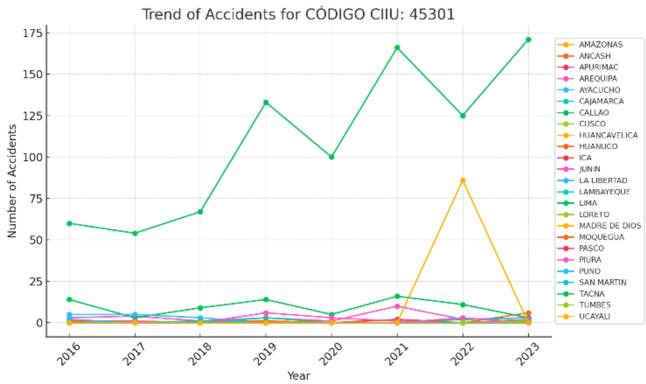

Fig. 3. Trend analysis for the building conditioning activity from 2016 to 2023

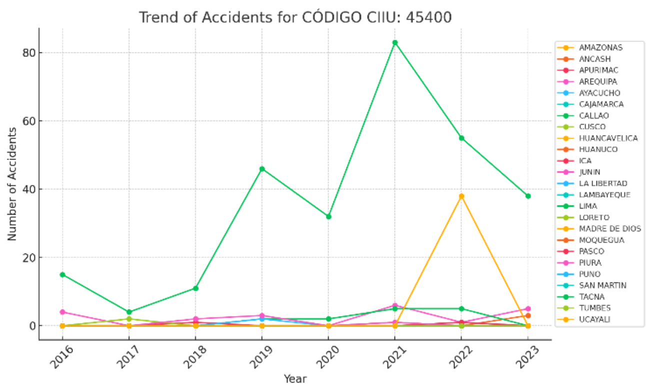

Fig. 4. Trend analysis for the building completion activity from 2016 to 2023

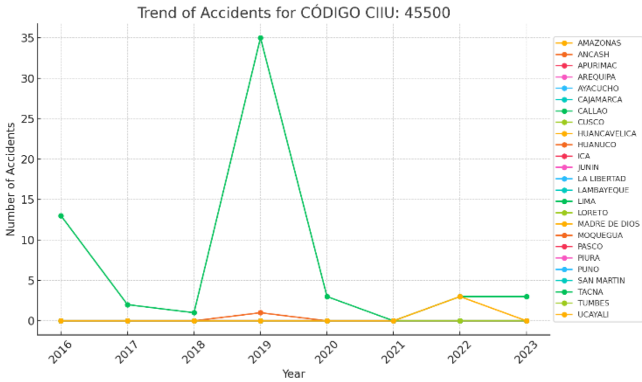

Fig. 5. Trend analysis for the rental of construction and demolition equipment with operators activity from 2016 to 2023

Trend Analysis for Top ISIC Codes

We will focus on the construction activities associated with the ISIC codes with the highest number of accidents to observe their trends over the years in Fig. 6 Activity construction of complete buildings or parts of buildings with ISIC code 45201, Fig. 7 Activity building conditioning with ISIC code 45201 and Fig. 8. Activity land preparation with ISIC code 45201.

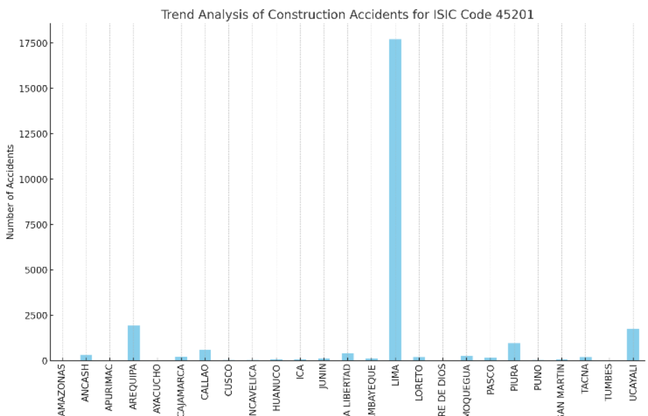

Fig. 6. Activity construction of complete buildings or parts of buildings with ISIC code 45201 from 2016 to 2023

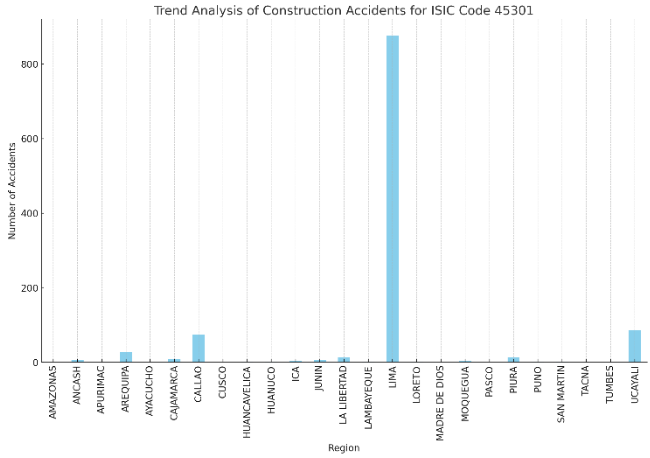

Fig. 7. Activity building conditioning with ISIC code 45301 from 2016 to 2023

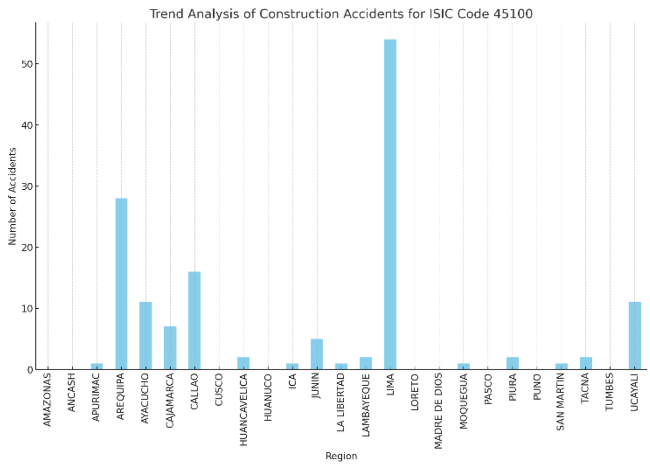

Fig. 8. Activity land preparation with ISIC code 45100.from 2016 to 2023

The previous bar graphs show the number of accidents reported in construction activity for the 05 regions with the highest number of accidents in Peru associated with their respective ISIC codes:

1. Activity rental of construction and demolition equipment with operators associated with the ISIC code 45201: This category presents the highest number of accidents, with significant figures in regions such as Lima, Arequipa and Ucayali.

2. Building conditioning activity associated with ISIC code 45301: This category also has notable accidents but is much lower than that associated with ISIC code 45201. Regions such as Lima and Ucayali show higher numbers.

3. Land preparation activity associated with ISIC code 45100: This category has the lowest number of accidents among the three main ones, with accidents spread over several regions but, in general, lower in comparison.

Trend analysis for all regions

Next, let's analyze the trends of accidents reported in construction activity in all regions from 2016 to 2023; we will observe Fig 9.

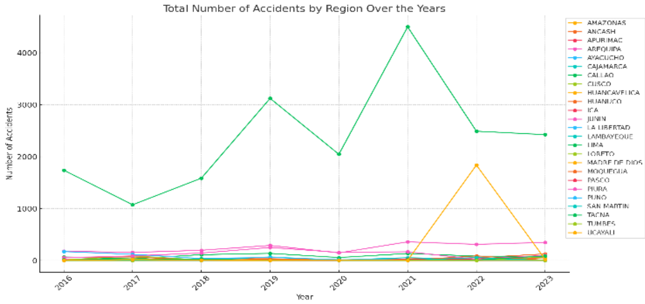

Fig. 9. Total accidents reported in construction activity in all regions from 2016 to 2023.

Trend analysis for all regions in the Fig. 9 reveals the following key points:

Lima: Dominates the accident numbers consistently, showing significant fluctuations across the years.

Arequipa, Ucayali, and Piura: Show a relatively higher number of accidents with noticeable trends of increase and occasional peaks.

Regions with Moderate Accident Numbers: Callao, La Libertad, Ancash, and Moquegua show moderate accident numbers, with some variability over the years.

Regions with Low Accident Numbers: Amazonas, Apurímac, Tumbes, and Madre de Dios maintain very low accident numbers, indicating minimal construction-related incidents.

Trend analysis for top 5 regions

We will plot the annual accidents for the top 5 regions: Lima, Arequipa, Ucayali, Piura, and Callao. We will graph the yearly number of accidents reported for the five regions with the highest number of accidents in construction activity, which are: Lima, Arequipa, Ucayali, Piura and Callao, as shown in Fig. 10

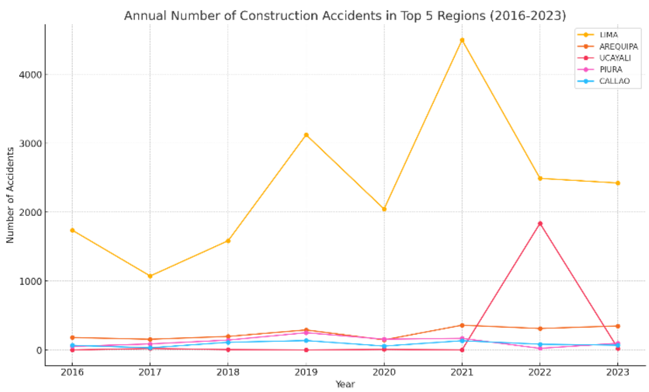

Fig. 10. Total accidents in construction activity reported in the five regions with the highest

number of accidents from 2016 to 2023.

The trend analysis for each of the five regions with the highest construction activities, including the slope and origin of the linear regression, is shown in Fig. 11 for Lima, Fig. 12 for Arequipa, Fig. 13 for Ucayali, Fig. 14 Piura and Fig. 15 Callao.

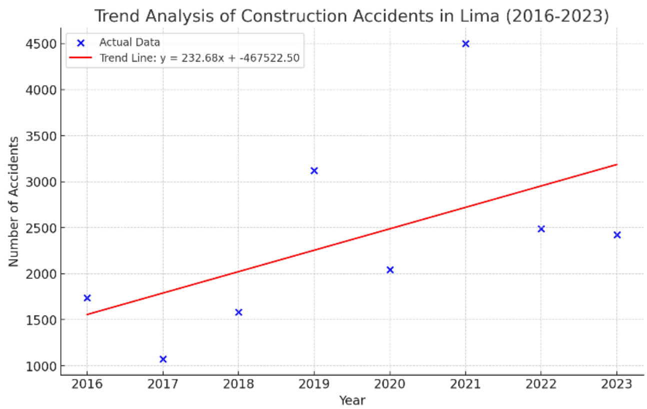

Fig. 11. Trend analysis of accident reports in construction activities in the Lima region from 2016 to 2023.

Trend analysis results for Lima

Slope: 232.68

Intercept: -467522.50

R-squared: 0.29

p-value: 0.171

Standard Error: 149.67

Interpretation: The trend analysis indicates an upward trend in construction accidents in Lima, with an average increase of approximately 233 accidents per year. However, the p-value suggests this trend is not statistically significant at the 0.05 level.

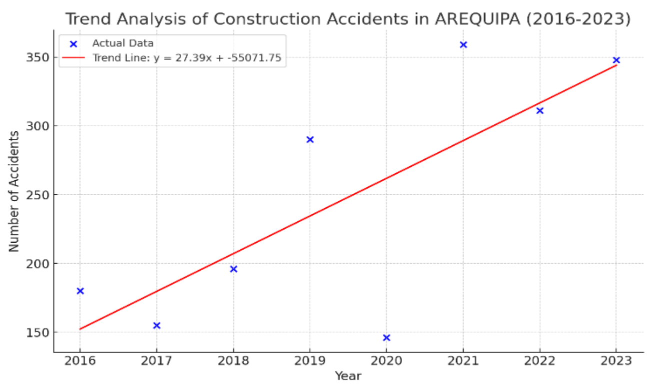

Fig. 12. Trend analysis of accident reports in construction activity in the Arequipa region

from 2016 to 2023.

Trend analysis results for Arequipa

Slope: 27.39

Intercept: -55071.75

R-squared: 0.58

p-value: 0.028

Standard Error: 9.54

Interpretation: Arequipa shows a statistically significant upward trend, with an average increase of about 27 yearly accidents.

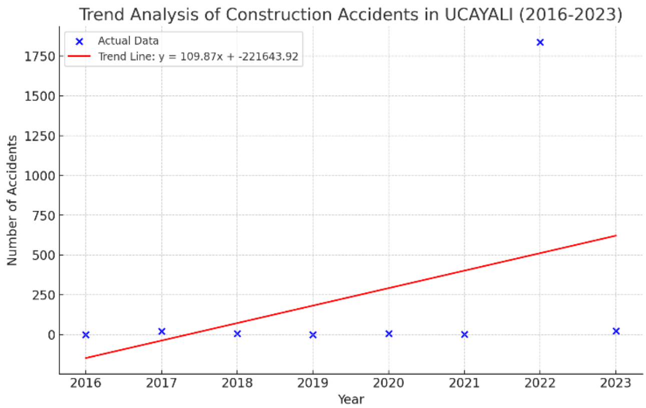

Fig. 13. Trend analysis of accident reports in construction activity in the Ucayali region from 2016 to 2023.

Trend analysis results for Ucayali

Slope: 109.87

Intercept: -221643.92

R-squared: 0.17

p-value: 0.305

Standard Error: 98.01

Interpretation: Ucayali shows an upward trend with a substantial increase of about 110 accidents annually. However, the trend is not statistically significant.

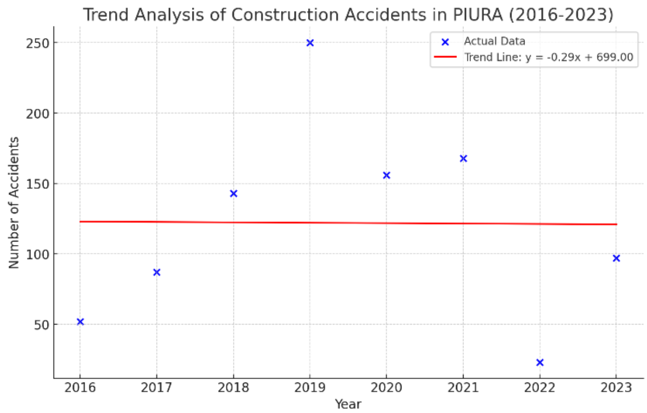

Fig. 14. Trend analysis of accident reports in construction activity in the Piura region from 2016 to 2023.

Trend analysis results for Piura

Slope: -0.29

Intercept: 699.00

R-squared: 0.000093

p-value: 0.982

Standard Error: 12.06

Interpretation: Piura shows a very slight downward trend, which is not statistically significant, indicating stable accident numbers over the years.

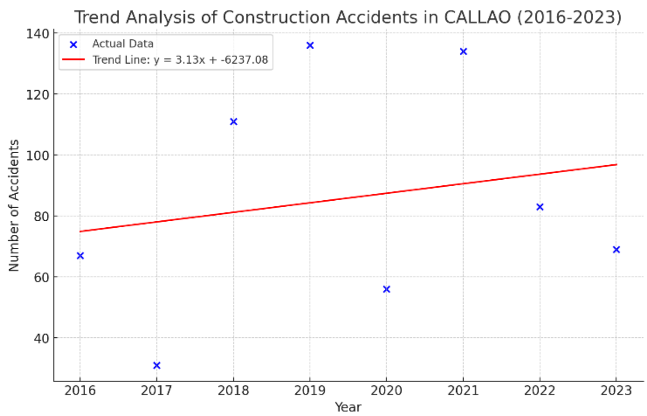

Fig. 15. Trend analysis of accident reports in construction activity in the Callao region from 2016 to 2023.

Trend analysis results for Callao

Slope: 3.13

Intercept: -6237.08

R-squared: 0.041

p-value: 0.630

Standard Error: 6.17

Interpretation: Callao shows a minor upward trend with an increase of about three accidents per year, which is not statistically significant.

Concluding:

Lima and Ucayali have the most significant upward trends, indicating growing construction activity or safety-related issues.

Arequipa also shows a steady increase, although at a lower rate.

Piura appears stable, with no significant increase or decrease in accidents.

Callao has a minor upward trend, suggesting a slight increase in accidents.

Step 3: ANOVA test

The results of the ANOVA Test to see if there are significant differences in the number of accidents between the five construction activities resulting in:

F-statistic: 2.75

p-value: 0.031

Interpretation:

The p-value is less than 0.05, indicating statistically significant differences in construction accidents among the five construction activities.

Step 4: Correlation Analysis

To understand the relationship between accident numbers and regions for the five classes of construction activities, we can calculate the correlation coefficients for the accident numbers in the 25 regions of the five classes associated with their ISIC codes.

Table 4 shows the values of the correlation matrix calculation for the number of accidents reported in construction activity by region.

Table 4. Correlation matrix of accident numbers by region

	0	1	2	3	4
1	1.00000	0.88733	0.87223	0.87688	0.84133
2	0.88733	1.00000	0.99468	0.99711	0.99250
3	0.87223	0.99468	1.00000	0.99813	0.99509
4	0.87688	0.99711	0.99813	1.00000	0.99423
5	0.84133	0.99250	0.99509	0.99423	1.00000

The correlation matrix shows the correlation coefficients for the number of accidents per region in the five construction activities:

The values range between 0.84 and 1.00, indicating strong positive correlations between the number of accidents in the five construction activities.

Comparative Analysis with Global Data

Comparing the findings with global data is valuable for comprehensively evaluating Peru's occupational health and safety (OHS) system in the construction sector. Here, we highlight key points of comparison using available global statistics.

Global Construction Accident Statistics

1. High-Risk Activities:

Globally, high-risk construction activities often include roofing, scaffolding, and working at heights. According to the International Labour Organization (ILO), these activities contribute significantly to construction accidents worldwide.

Comparison: ISIC code 45201 in Peru, which corresponds to general construction activities, including building construction and civil engineering, recorded the highest number of accidents (25244 incidents). This aligns with global trends, which indicate that general construction activities are high-risk.

2. Regional Disparities:

Urban areas with extensive construction projects in many countries report higher accident rates. For instance, regions like New York [7] in the United States and major cities in China [6] report higher incidents due to more intensive construction activities.

Comparison: Lima, Arequipa, and Ucayali had the most construction accidents, similar to global patterns where major urban centres have higher accident rates due to increased construction activities.

3. Accident Rates:

The ILO estimates that construction workers are three to four times more likely to die from accidents at work compared to workers in other sectors. In the E.U., the construction sector has one of the highest rates of fatal accidents.

Comparison: The Peruvian data did not provide specific fatality rates; the high number of accidents in regions like Lima suggests similar risks. Analyzing the severity of these accidents would provide more context.

4. Effectiveness of OHS Systems:

Countries with stringent OHS regulations, such as those in Scandinavia, report lower accident rates. Practical safety training, regular audits, and vigorous enforcement of safety regulations contribute to these lower rates.

Comparison: The findings from Peru indicate a need for enhanced safety regulations and targeted training, suggesting that the current OHS system may not be as effective as those in countries with lower accident rates.

5. Statistical Significance and Trends:

Globally, trends indicate decreased construction accidents in regions with improved safety measures and technological advancements in construction practices.

Comparison: The ANOVA test in Peru showed significant differences in accident numbers among ISIC codes, indicating specific areas needing improvement. The overall trend in Peru is an increase in accidents, highlighting an urgent need for improved safety measures.

4. CONCLUSION

The evaluation of the occupational health and safety system in the construction sector in Peru highlights significant regional and categorical disparities in the occurrence of accidents. The high accident rates in regions such as Lima, Arequipa and Ucayali, particularly in the "Construction of complete buildings or parts of buildings" associated with ISIC code 45201, underscore the need for targeted safety interventions. The positive correlations suggest that regions with high accident rates in one construction category also tend to have high rates across other categories.

We propose the following recommendations to improve the OHS system:

1. Enhanced Safety Regulations: Strengthen safety regulations and enforcement in high-risk regions and construction activities.

2. Focused Training Programs: Implement targeted safety training programs for workers and supervisors in high-risk areas.

3. Regular Safety Audits: Conduct regular safety audits and inspections, particularly in regions with consistently high accident rates.

4. Data-Driven Policy Making: Utilize accident data to inform and refine safety policies, ensuring they address the specific needs of different regions and construction activities.

This study provides a foundation for improving occupational health and safety in Peru's construction sector, contributing to safer workplaces and better protection for construction workers.

Comparing Peru's construction accident data with global trends underscores the need for significant improvements in its OHS system. Enhancing safety regulations, implementing focused training programs, conducting regular safety audits, and adopting data-driven policies are crucial. Learning from global best practices can help Peru reduce construction accidents and improve worker safety, aligning with successful strategies observed in countries with more effective OHS systems.

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