Entre

CIENCIA e INGENIERIA 4

Amanda Fernandes Pereira da Silva
(Organizadora)

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APRESENTAÇÃO

A coleção “Entre Ciencia e Ingenieria 4” é uma obra que compreende os processos sob os quais se desenvolve, aplica e divulga a ciência, tecnologia e a inovação. Seu objetivo consiste em difundir trabalhos científicos que abrange diversos campos da Ciência e Engenharia que compõem os capítulos.

O volume abordará de forma categorizada e clara pesquisas e publicações com o objetivo central de analisar processos que possam ser utilizáveis em projetos e/ou trabalhos futuros. Além disso, apresenta uma análise ao desenvolvimento de temáticas que envolvem a saúde pública e coletiva, área das engenharias e ciência.

Desta forma, esse material se torna bem interessante por constituir temas, conhecimentos acadêmicos desenvolvidos e discutidos por diversas instituições de ensino e pesquisa do país e fora do país. Por isso, para necessária compreensão comum e explicitar trabalhos de forma altamente eficaz, a Atena Editora é capaz de oferecer e difundir a transferência de conhecimento com os mais debates centrados da liderança da ciência e engenharia com esta mais nova coleção.

Amanda Fernandes Pereira da Silva

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CAPÍTULO 9

REDUCTION OF WORKPLACE ACCIDENT RATES USING MATHEMATICAL STATISTICAL MODELS

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ABSTRACT: The objective of this research was to select the best regression model that would allow identifying the variables of the Occupational Health and Safety Systems, which have a greater impact on the occurrence of accidents, to project programs of improvements in order to reduce accident occurrence rates. The research was conducted with a sample of 24 small and medium-sized Ecuadorian companies. The causal factors to be investigated were Occupational Health Management, Occupational Risk Prevention Management, Management of Natural Hazards / Anthropic Risks and Document Management. The mathematical models subjected to analysis to determine the relationship between the causal factors and the number of accidents were the Poisson, Negative Binomial and Logistics Regression models. STATGRAPHICS Statistical Software was used to determine the model with the best goodness of fit. Statistical inference was made by comparing Poisson, negative binomial and logistic regression models, the latter being the one that presented the best fit. The application of the designed intervention plans made it possible the observation of improvements in the performance of these systems, which was evidenced by a significant reduction in accident rates.

KEYWORDS: Workplace Accidents, Regression Models, Multivariate Statistics, Logistics Models, Safety and Health Audits, Performance Improvement.

1 | INTRODUCTION

Authors such as Sanchez [8], Forastieri [2] explain that accidents constitute a large source of cost generation. The economic costs of occupational and work-related injuries increase rapidly, according to a report by the International Labor Organization [10]. Although, it is impossible to set a value on human life, compensation figures indicate that the cost of illnesses and accidents at research represents about 4% of the world's gross domestic product (about $2.8 trillion) in terms of lost research time, production interruptions, research absenteeism, disease treatments, incapacity, and survivor's benefits. The developed countries are affected by these figures, despite the high technological development, [5], [7], [11].

At international and national levels, there are now alarming figures for the occurrence of occupational accidents. The most recent OIT calculations [11] show that there are 2.3 million

annual deaths and 317 million work-related accidents (more than_5000 per day) and for each fatal accident there are between 500 and 2000 injuries [3], [1].

Statistics such as these show the need to carry out scientific research that contributes to the reduction of these indicators, thereby improving the working conditions (as these are the ones that favor the occurrence of those events), management systems of health and security at work, as well as physical, psychological, and social well-being of the human factor that performs its functions in work environments.

At present, the application of mathematics to the modeling of various current phenomena has been expanded, then, it is necessary to link this science with safety and health in work environments, to reduce the incidence of inadequacies in the performance of Management Systems of Safety and Health at Work.

Hence, the objective of this research is to fit a statistical model for the analysis and identification of the factors that have the greatest influence on the occurrence of occupational accidents (counting variable) and reduce workplace accident rates, by improving the effectiveness of the occupational health and safety management system.

The methods used and the main results obtained are explained.

2 | MATERIALS AND METHODS

The diagnosis of the performance of the management system and its relationship with the occurrence of accidents was carried out using the procedure shown in Figure 1.A sample of 24 representative Ecuadorian SMEs Guayas province of different sectors, with high accident rates, was selected. The definition of variables was made from the checklist for the performance evaluation of the Management System in Health and Safety at Work, shown in Table 1 [6].

The diagnosis of the performance of the systems was carried out by applying the checklist shown in Table 1, in correspondence with the legal requirements in Ecuador and the ISO 45001: 2018 standard [4]. The causal factors to be investigated are Occupational Health Management, Occupational Risk Prevention Management, Management of Natural Hazards / Anthropic Risks and Document Management. The application of this checklist allowed the calculation of the System Efficiency Index from the sum of the points assigned to all the elements of the checklist. If the value of the index is less than 80%, it is considered that the efficiency of the system is not satisfactory and it is necessary to evaluate the risks for occupational health and safety, based on the results of the checklist, as well as the damage that these can cause. evaluating its probability of occurrence, severity and vulnerability.

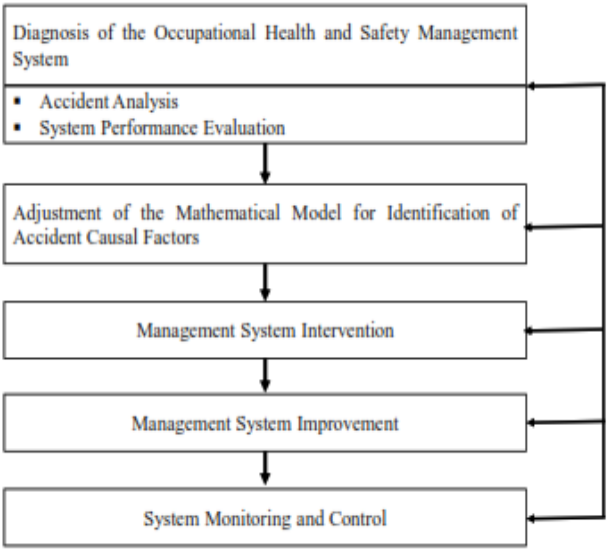

Figure 1: Procedure for the diagnosis of the Management System and its Relationship with the occurrence of accidents

TYPES OF MANAGEMENT, ELEMENTS, SUB-ELEMENTS
Occupational Health Management
1.- Statistical Information (2 Sub- Elements)
2.- Health Surveillance (9 Sub- Elements)
3.- Investigation of Incidents, Accidents and Occupational Diseases (4 Sub- Elements)
Occupational Risk Prevention Management
4.- identification of Risk Factors (7 Sub- Elements)
5.- Evaluation of Risk Factors (13 Sub- Elements)
6.- Control and Monitoring of Risk Factor Control Measures (12 Sub- Elements)
7.- Training (2 Sub- Elements)
8.- Use of Personal Protective Equiment (15 Sub- Elements)
9.- Security in the Purchase of Inputs (2 Sub- Elements)
Management of Natural Hazards/ Anthropic Riscks
10.- Emergency Response Plans (6 Sub- Elements)
11.- Plans for the Prevention and Control of Grave and Major Accidents (15 Sub- Elements)
Document Management
12.- Policy-Corporate Social Responsibility (8 Sub- Elements)

Table 1: Simplified Checklist for management Systems Diagnosis

The models selected for the analysis of accident rates, as shown in Figure 2, were Poisson, Binomial Negative and Logistics Regressions since, the dependent variable is a counting of accidents. The independent variables are the four types of management evaluated by means of the checklist.

The processed data were obtained from the application of the checklist, Table 1, for performance evaluation of Health and Safety Management Systems at the selected SMEs. Model comparison and selection were made by means of Regression Analysis, Analysis of

Variance, Goodness of Fit Tests and other statistical inference methods. The model with the best fit, Logistics Regression, made it possible to identify the Occupational Risk Prevention Management, and its components, as the causal factors of the accident rates in the SMEs selected for the present study.

Data processing and analysis, were made by means of the statistical software Statgraphics [9], to determine the mathematical model with the best fit to find the causal factors of the recorded accident rates. All this made it possible the implementation of measures to improve the performance of management systems and reduce accident rates in the SMEs under study.

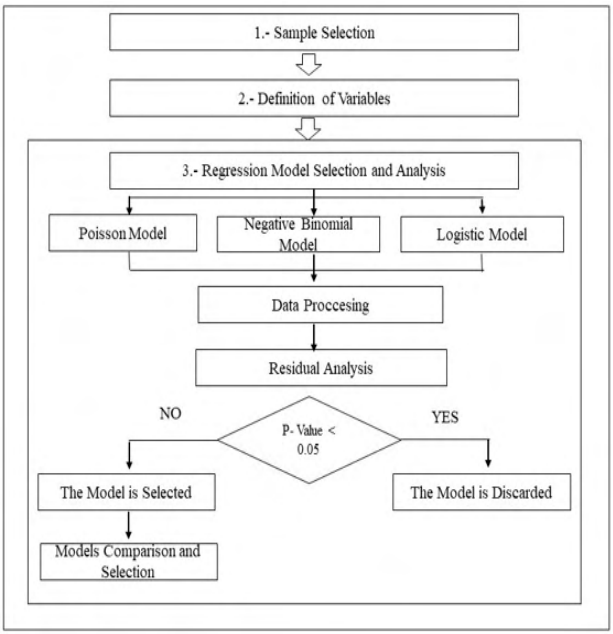

Figure 2: Procedure for identification of Accident Causal Variables

3 | ANALYSIS AND RESULTS

Table 2 shows the three models fitted by applying the statistical software Statgraphics. The best fitted model was the Logistics Regression Model. Table 3 shows a comparison of the three models obtained from the statistical software application. The Logistics Regression model presented a P-value lower than 0.05 for the Analysis of Deviations, so there is a statistically significant relationship between the variables, with a confidence level of 95.0%. Furthermore, the P-value for the residuals is greater than 0.05, indicating that the model is not significantly worse than the best possible model for these data with a confidence level of 95.0% or greater. The percentage of deviation of the number of accidents explained by

the model is equal to 66.1381%. This statistic is similar to the usual R-Squared statistic. The adjusted percentage, which is more appropriate to compare models with different numbers of independent variables, is 53.046%. The highest P-value for likelihood ratio test is 0.0000, which belongs to Prevention Management. Hence, that term is statistically significant at the 95.0% confidence level. It is observed that this model presents better results than the Negative Binomial Regression.

The Poisson model presents the P-value for the residuals less than 0.05, indicating that it is significantly worse than the best possible model for these data, with a confidence level of 95.0%.

The components of the Prevention Management level variable: the identification of hazards and risks for OSH; evaluation; control and monitoring of risk control measures; training, the use of safety equipment for personal protection and security when purchasing supplies; are the ones that affect the occurrence of occupational accidents and the weaknesses identified in the diagnosis of the OSH Management System performance carried out in the SMEs studied, and allowed to verify in practice the results obtained by the mathematical analysis performed.

Regression	Model Fitted
Poisson	Number of Accidents = exp (3,244-0,069*Health Management - 0,185 Prevention Management) Eq. (1)
Negative Binomial	Number of Accidents = exp (3,397- 0,075* Health Management- 0,196* Prevention Management) Eq. (2)
Logistics	Number of Accidents = exp (eta) / (1+exp (eta)), Where eta = 6,868 – 0,730 * Prevention Management Eq. (3)

Table 2: Mathematical Fitted Regression Models

Inference Criteria	Poisson Model	Negative Binomial Model	Logistics Model
Explained Percentage of Deviations	61,491	62,360	66.138
Adjusted Percentage	56,977	52,435	53,046
Significative Variables (Likelihood Ratiotest)	• Health Management • Prevention Management (Máx. P-Value= 0,0001)	• Health Management • Prevention Management (Máx. P-Value= 0,0165)	• Prevention Management (P-Value= 0)
Residual Analysis	P-Value < 0,05	P-Value > 0,05	P-Value > 0,05
Analysis of Deviations	P-Value < 0,05	P-Value < 0,05	P-Value < 0,05

Table 3: Comparison of Fitted Regression Models

The identification of the components that more affected the system performance made it possible its level of intervention.

This has been carried out at the OSH Management Systems, improved their behavior, the degree of compliance with the training actions and the level of competence

in OSH of the workers. These aspects denote progress in the quality of life by encouraging the participation of workers in preventive activities and project preventive management for the gradual improvement of current levels of system performance; all of which, together with the results obtained from its adoption and implementation, allowed to verify compliance with the research hypothesis.

The identification of the components that more affected the system performance made it possible its level of intervention.

The rational and comprehensive application of the procedures proposed in the 24 Ecuadorian SMEs, made it possible to verify their feasibility and convenient use as an effective methodological instrument for identify the main weaknesses of the OHS Management System, as well as a significant 50% reduction in the occurrence of major non-conformities. The results of the effectiveness indicators, once the intervention has been carried out at the OSH Management Systems, improved their behavior, the degree of compliance with the training actions and the level of competence in OSH of the workers. These aspects denote progress in the quality of life by encouraging the participation of workers in preventive activities and project preventive management for the gradual improvement of current levels of system performance; all of which, together with the results obtained from its adoption and implementation, allowed to verify compliance with the research hypothesis.

4 I CONCLUSIONS

The identification and use of mathematical statistical models to determine the elements of the OSH Management System, which are causal factors of high rates of occupational accidents, within the framework of the specific procedure developed for diagnosis, constitutes a methodological novelty, because it made possible the choice of the prioritized aspects for the application of intervention programs that contribute to the improvement of the Management System of Health and Safety performance, all of which has allowed an increase in the quality of life in companies, through a significant reduction of workplace accident rates, as was demonstrated in its application to the 24 SMEs under study. Besides this, the approach used in the present investigation, exceeds the evaluations based on traditional accident rates indicators, because the last ones do not use statistical inference methods for decision-making, leading to a true identification of occupational hazards and measures to make possible their preventive elimination.

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