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Fire Regulations in Industrial Companies and the Level of Impact and Risk: The Case of the Municipality of Soledad, Atlántico

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ABSTRACT

The risk of fire is ubiquitous: no matter the human activity, there will always be the associated probability of fire generation. However, if started, the potential impact of fire will depend on different factors such as the activity, the materials stored, and the prevention and control measures deployed, which includes the minimum requirements of current legislation. The main objective of this research is to understand the factors that influence compliance and non-compliance with fire regulations by large companies, considering the case of the municipality of Soledad, Colombia. As part of the methodology, a descriptive statistical approach was used for the analysis, considering companies' compliance in recent years, and related these data to the level of risk and the impact that a conflagration would have on premises, people, and the environment. A Chi-Square association test was applied, and additionally, a Cramer's V test was applied to determine the magnitude of the association. The database used for the study was provided by the Volunteer Fire Department of Soledad, Colombia. They are responsible for carrying out the compliance control audits of the companies in the municipality. Among the results, compliance with the standards by most companies and a statistically significant association between impact, level of risk, and variables such as emergency brigades, fixed fire systems, among others, were observed.

1. INTRODUCTION

The imminent danger before a fire leads to take measures for prevention and action to minimize the possibility of material, environmental and human losses, considering that, once materialized, it does not distinguish between its origin and the possible consequences for the company and its environment, given that the speed of spread and the damage it could cause can be incalculable if it is not controlled promptly [1]. Therefore, it is vital to establish safety measures to prevent and control, both at the level of home and industrial activities [2, 3].

Enhancing the survival instinct of the occupants of any building before the development of the initial fire is a goal to provide life safety during emergencies that can be mitigated with extinguishing and prevention methods, according to NFPA [4].

Globally, there are generally accepted standards for fire protection, such as NFPA 101 Standard [5]. In the case of Colombia, building resistance guidelines are established considering earthquakes [6], including fire protection requirements, which must be observed in all facilities, workplaces, and civil infrastructure, whether for public or private use, and correspond to the minimum conditions for the attention of events that have a negative impact on the generation and spread of fire. The design of any structure or building must be based on safety, well-being, hygiene, and comfort for the people who will occupy it. In case of fortuitous phenomena such as fires, the need arises to understand what the advantage is of having a clear structure that defines the protection against them, according to the levels of current risk, allowing to reach solutions that give way to an adaptation without affecting safety.

Fire protection corresponds to measures, regulations, and standards that seek to prevent the start and spread of fire [7]. Likewise, they cover the actions and tools needed to avoid the beginning of fire to the detection and extinguishing mechanisms [8]. Fire protection is divided into three main branches, according to the publication of Oklahoma State University [7]:

1. Preventive protection. It focuses on analyzing the potential sources of risks and consequences associated with the activities and environments where they are carried out.
2. Passive protection. It focuses on preventing the onset and development of fire and limiting its impact on people and facilities.
3. Active protection. It focuses on extinguishing fire once it has started and begins to spread.

In the municipality of Soledad, located in the department of Atlántico, there are several antecedents of fires where human, economic, and environmental losses have occurred [9, 10]. Therefore, the industrial part of the municipality has adapted to the set of standards, requirements, and procedures of mandatory observance. These standards are established, registered, verified, and controlled in compliance with the basic conditions of prevention measures, structural

constructions, and fire extinguishing. Abiding by the minimum safety standards is required by Colombian regulation, defined by legislation as is the CTS (Colombian Technical Standard) No. 2301, 1669, and 2885 supported by the international regulations of entities such as the NFPA.

The evaluation and certification is established using what is said by Congreso De La Republica [11].

"The fire departments are the competent bodies for carrying out the tasks of inspections and technical reviews in fire prevention and human safety in public and private buildings and particularly in public commercial and industrial establishments and will inform the competent entity of compliance with safety regulations in general. Similarly, to develop massive events and/or pyrotechnics, they will enforce all current laws regarding the integral management of fire risk and related calamities".

Exposed this, the entity in charge of verifying that this regulation is observed within the municipality of Soledad is the Volunteer Firefighter Corps of Soledad.

This research aims to determine the level of compliance with the integral management of fire risk in the companies of the municipality of Soledad - Atlántico. On the one hand, a comparative analysis of adherence to current comprehensive fire risk management standards through a verification control is carried out. On the other hand, the authors tried to find a statistically significant relationship with the level of risk and impact by applying an analysis of compliance with the laws and regulations of prevention and integral management of fire risk of the large companies in the municipality of Soledad – Atlántico.

2. METHODS

Companies in Soledad - Atlántico are the population used to carry out the research study, segmented according to their size, business name, and activity and whose data on compliance with fire regulations was provided by the Volunteer Fire Department Soledad, Colombia. As a sample analyzed from the database, the total of 211 records of companies in the industrial sector available at the time of analyzing the data was taken because most of them are in the ranking of large companies, according to their number of employees and their level of risk, tending to be the latter higher than the average of companies in other sectors. The database used in the analysis was in a CSV (comma-separated values) format, created in Microsoft Excel®, and it stored the transcriptions of the original records of inspections done by the Volunteer Fire Department of Soledad in each company, applying a checklist designed by them. Each record included the enterprise's name, risk level, impact, and compliance or not compliance for each of the items in the checklist, for 46 fields. Due to a confidentiality agreement, the names of the companies and the specific compliance data of each cannot be publicly disclosed.

The audit checklist, originally used for the verification of fire measures in companies and subsequent storage in the database by the Soledad Volunteer Fire Department, is a technical inspection format (in its third version of January 2018), which contains 40 minimum standards, included in 11 numerals, where the first 3 are general information of the company. A synthesis of this checklist is shown in Appendix A. From the 4th to the 11th numeral, the variables evaluated for the certification of compliance with fire regulations are considered:

1. General requirements for fire protection in the building: These present the minimum standards that ensure that the primary purpose of safeguarding human lives is met in the event of a fire in a building [6] The requirements considered in this numeral are evaluated in each company, no matter the type of building.
2. Emergency Plan: It is a set of measures used as a guide to develop and establish procedures for the attention of an emergency, reducing the chances of significant damage to human life, the environment, and material goods for which this action plan is responsible for its safety.
3. Emergency Brigades: Voluntary occupation by a group of employees in companies, trained to prevent and pay attention to emergencies generated inside or outside the company. These must be equipped with safety and fire extinguishing implements necessary to face any emergency in its first stage of development [12].
4. Portable fire systems: Portable fire systems are largely effective and are always available, thanks to their operability. These provide security and generate reliability, and, at the same way, they are mainly helpful to exemplify them for caution and thus avoid fire and refire such as fire extinguishers [13, 14].
5. Fixed fire system: they seek to attack a fire in its early stages to reduce, control, or mitigate its effects. Usually, an extinguishing agent is used, which is released on the fire according to the systems installed in the building [4, 15].
6. Electrical circuits: Electrical elements, devices, and equipment connected to protect against increases in voltage and current in electrical circuits [16].
7. Piping system for fluid transport: These systems are responsible for moving ducts from one place to another. Through these, the supply to the processes is optimized and improved, while the safe supply of liquids, gases, and other substances, duly marked and measured, is sought [17].
8. Chemicals: substances in solid, liquid, gaseous or colloidal state with physicochemical characteristics can cause damage to people, installations, or the environment.

The type of research developed considered a quantitative – descriptive approach, that is, based on the analysis of quantitative data, where a statistical analysis was applied with a Pearson Chi-Square test to determine the association between the variables with the impact, with the level of risk or with both. The statistical software JASP 0.16v was used for the analysis, applying the Pearson Chi-Square test. The test was conducted to analyze the compliance by aspect in each variable versus the level of risk and the level of impact (in a separate analysis). The original database of 211 companies had to be purged of repeated or incorrectly typed records, considering a final total of 185 companies for the analysis. For the statistical analysis, the null hypotheses considered that there was no significant association between a given aspect in a variable and the level of risk or the level of impact. Similarly, the association test results by the level of risk and level of impact were organized in a contingency table.

The level of impact was defined as the approximate number of square meters that the establishment has in front of the occupied area that can damage the environment. That is, the level of impact is associated with the fact that the larger the

space occupied by the company's facilities, the more significant the impact it can potentially have on its surroundings once the fire starts or leaking occurs (for example, neighboring businesses or the nearby community). All firefighters corps must use this characterization of the level of impact throughout Colombia, according to the national regulation [18], and Firemen are trained to identify and estimate the level of impact when applying the checklist on a company. The level of impact is divided in six levels:

- Level 1: 1/20 m^2
- Level 2: 21/100 m^2
- Level 3: 101/1,000 m^2
- Level 4: 1,001/2,0000 m^2
- Level 5: 20,001/30,000 m^2
- Level 6: > 30,000 m^2

On the other hand, the level of risk was defined according to the economic activity carried out by the organization and the risk they represent in the environment. The establishments are grouped into six levels or categories that are:

- Level 1: Mild
- Level 2: Moderate
- Level 3: Ordinary 1
- Level 4: Ordinary 2
- Level 5: Extra risk
- Level 6: Special risk condition.

A p-value <0.05 was considered for the association test, which indicated a statistically significant association between variables. Likewise, the Cramer's V statistic was applied, assuming a strong association with values close to 1.0 and a weak association with values close to 0.0, considering that the contingency table generated exceeded the dimensions of 2 x 2. Cramer's V test determined how strong the association was in those aspects of a variable in which a significant statistical association was found between the level of risk, the level of impact, or both. This analysis was complementary to Pearson's Chi-square test, allowing the strength of the association to be identified. Another advantage of applying a Cramer's V test is that it does not depend on the size of the table and is based on a Chi-square adjustment [19].

3. RESULTS

The variables considered in the numerals from 4 to 11 were submitted to the Pearson association test, as described in the methods section. It was possible to find an association between the impact and four aspects of the eight variables analyzed. Similarly, a statistical association was found between six aspects of these variables and the level of risk. Table 1 and 2 show the contingency tables.

An association was found between the impact and the variables of the piping system for the transport of fluids, and chemical substances ($p<0.05$). In the case of the first, the association was found in the aspect related to leaking protection systems, which is related to the installed protection of anti-drip system in flanges, couplings, and joints. The magnitude of Cramer's V Test was superior to 0.2. In the case of the latter, two aspects were statistically significant: the existence of an anti-flare-up kit of substances and the presence of the chemical compatibility matrix for storage. The Cramer's V Test showed a magnitude of the association was greater than 0.2 (See Table 1).

Concerning the level of risk, a statistically significant association was found with this and compliance with 4 of the variables inspected: emergency brigades, portable fire systems, electrical circuits, and piping systems for the transport of fluids ($p<0.05$). The Cramer's V test showed a magnitude in the association between 0.2 and 0.4. It should be clarified that level 2 risk was not found in any of the companies analyzed in the study, so it was not included in Table 2.

Table 1. Association between Impact and aspects of the variables assessed

Variable	Aspect		Impact							p-Value	df	Cramer's V
			1	2	3	4	5	6	Total			
Piping system for fluid transport	Protection of anti-drip system in flanges, couplings, and joints (Piping system for fluid transport)	Comply	1	13	69	78	8	7	176	0.044	5	0.248
		(%)	50.00	92.86	94.52	97.50	100.00	87.50	95.14			
		Not Comply	1	1	4	2	0	1	9			
		(%)	50.00	7.14	5.48	2.50	0.00	12.50	4.87			
Chemicals	Existence of chemical anti-skid kit	Comply	2	14	67	73	4	7	167	0.005	5	0.302
		(%)	100.00	100.00	91.78	91.25	50.00	87.50	90.27			
		Not Comply	0	0	6	7	4	1	18			
		(%)	0.00	0.00	8.22	8.75	50.00	12.50	9.73			
	Chemical Compatibility Matrix	Comply	2	9	70	74	8	8	171	0.002	5	0.317
		(%)	100.00	64.29	95.89	92.50	100.00	100.00	92.43			
		Not Comply	0	5	3	6	0	0	14			
		(%)	0.00	35.71	4.11	7.50	0.00	0.00	7.57			

Table 2. Association between level of risk and aspects of the variables assessed

Variable	Aspect		Impact						p-Value	df	Cramer's V
			1	3	4	5	6	Total			
Emergency brigades	Emergency brigades training	Comply	0	1	8	14	40	63	0.01	4	0.269
		(%)	0.0	7.1	32.0	24.6	46.0	34.1			
		Not Comply	2	13	17	43	47	122			
		(%)	100.0	92.9	68.0	75.4	54.0	65.9			
Portable fire systems	Fire extinguisher status check	Comply	2	13	25	57	87	184	0.015	4	0.258
		(%)	100.0	92.9	100.0	100.0	100.0	99.5			

		Not Comply	0	1	0	0	0	1			
		(%)	0.0	7.1	0.0	0.0	0.0	0.5			
		Comply	1	11	22	54	82	170			
Fixed fire system	Fire cabinets	(%)	50.0	78.6	88.0	94.7	94.3	91.9	0.044	4	0.23
		Not Comply	1	3	3	3	5	15			
		(%)	50.0	21.4	12.0	5.3	5.7	8.1			
	State of electrical installations. Pipe signaling	Comply	2	11	23	53	58	147			
		(%)	100.0	78.6	92.0	93.0	66.7	79.5	0.001	4	0.312
		Not Comply	0	3	2	4	29	38			
Electrical circuits		(%)	0.0	21.4	8.0	7.0	33.3	20.5			
		Comply	1	11	11	45	49	117			
	Automatic extinguishing system	(%)	50.0	78.6	44.0	78.9	56.3	63.2	0.01	4	0.269
		Not Comply	1	3	14	12	38	68			
		(%)	50.0	21.4	56.0	21.1	43.7	36.8			
		Comply	1	13	20	54	82	170			
Piping system for fluid transport	Signalling and demarcation of fluid transport pipes	(%)	50.0	92.9	80.0	94.7	94.3	91.9	0.03	4	0.241
		Not Comply	1	1	5	3	5	15			
		(%)	50.0	7.1	20.0	5.3	5.7	8.1			

4. DISCUSSION

The analysis carried out in this article focused on the search for the relationship of the items of the numerals analyzed in the database of the firefighters of the municipality of Soledad, Atlántico of companies inspected concerning compliance with fire regulations. This represents a case study to analyze the association between the level of risk and the level of impact against variables such as fire brigades, fixed and mobile fire systems, among others. Although the level of impact depends on the analysis done at the moment of the inspection by the firefighters, it is based on Colombia's national regulation, centered on the area occupied and the potential damage a fire or fortuitous event might cause on the company and its surroundings. We consider this perspective of assessing the impact level acceptable, but it might be convenient to use another view, considering other elements of the impact as mentioned by Kodur et al. [20].

A statistically significant association was found with respect to compliance in the variables Piping system for fluid transport, Chemicals, and the level of impact that companies can generate on the environment, facilities, and people. In this way, it was highlighted that compliance with the anti-drip protection system of pipes carrying hazardous fluids was observed and concerning aspects of the existence of spill-over systems and product compatibility in relation to chemical substances. In this case, compliance predominates, especially among companies with impact levels between 3 and 4, that is, companies whose relationship between available area vs. occupied area ranges around 5% to 10% (Levels 3 and 4, as shown in the methods section). This result can be given since the size of the companies in the sample was mainly between medium and large-sized. Regarding the magnitude of the association, a moderate magnitude was found according to the Cramer's V test results since values between approximately 0.25 and 0.32 were observed.

On the other hand, compared to the level of risk associated with the company's economic activity, an association was observed between this, and five of the nine variables recorded in the database of the firefighters of Soledad. It was observed that there is a statistically significant association between emergency brigades, portable and fixed systems, electrical circuits, and piping systems. It stands out from the rest of the variables mentioned, where compliance predominated, the one corresponding to the emergency brigades, where non-compliance predominated (65% of the companies did not comply). This highlights that training against fire and coaching in the brigades of the companies in the municipality is a critical aspect to improve. Likewise, like the impact, the Cramer's V test showed a moderate association with respect to the variables and the level of risk since they were above 0.22.

5. CONCLUSIONS

As could be seen in the research carried out, the data obtained show a statistically significant relationship regarding the association between the level of fire risk and the impact generated in organizations compared to the variables studied. In turn, it can be said that the fire regulations are correctly applied by the vast majority of companies subject to the technical inspection applied by the Volunteer Fire Department of Soledad, showing that most of the companies that are at the highest levels tend to comply with the numerals evaluated, with a 95% confidence interval.

The fact that organizations do not comply with some numerals for reasons such as ignorance of the applicability of the standard or its inadequate application cannot be ignored. That is why it is important to mention that, although there are competent authorities in charge of monitoring the correct application of the fire-fighting rules in the municipality, it is the commitment of all companies to continuously monitor of their systems, understanding that it depends on maintaining optimal security conditions for the organization and those who make up it. It is highlighted that the training of personnel who will face emergency situations derived from fires is a critical aspect, in which the companies of the study showed weakness. That is why it is necessary to highlight the need for managers' and officials' commitment to fire prevention measures, starting from the fundamental: personnel training and coaching.

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APPENDIX

Appendix A. synthesis of the checklist used by the firefighters in the municipality of Soledad, Atlántico

Numeral	Description / Evaluated aspects
1. General information	Company's legal name, address, insurance company, etc.
2. Self-declaration	List of the areas of the establishment
3. Categorization	Level of impact Level of risk Dimension of facilities Area
4. General requirements for fire protection in the building	Devices for the interruption of gas, electric fluid, combustible, flammable, or oxidizing fluids access roads for the fire department Availability of universal connection valves for the fire department First aid kits Signaling of traffic areas Access to fire department lines Existence of a vulnerability analysis
5. Emergency Plan	Existence of a documented emergency plan Socialization of the emergency plan Emergency Exits and their signaling
6. Emergency Brigades	Formation of the emergency brigade Emergency brigade training Ratio of employees in the emergency brigade
7. Portable fire systems	Types of fire extinguishers used Area of coverage of fire extinguishers Fire extinguisher maintenance program Demarcation of fire extinguishers Fire extinguisher status check
8. Fixed fire system	Existence of fixed fire protection systems Existence of hydraulic network System testing under NFPA standard Annual inspection by the fire department network Maintenance program for fixed systems Pyrometric test Fire Cabinets
9. Electrical circuits	State of electrical installations. Pipe signaling Fire detection system inside electrical pipelines Automatic extinguishing system
10. Piping system for fluid transport	Signaling and demarcation of fluid transport pipes Protection of anti-drip system in flanges, couplings, and joints (Piping system for fluid transport)
11. Chemicals	Existence of a program for handling chemicals Existence of chemical anti-skid kit Chemical Compatibility Matrix Listings of chemical products Chemical storage Availability of safety showers