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A study of situational circumstances related to Spain's occupational accident rates in the metal sector from 2009 to 2019

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ABSTRACT

The metal sector encompasses a variety of economic activities, such as metallurgy and the manufacturing of metallic elements. These activities represent great diversity in production processes. Worker-related characteristics are particularly important in these processes and the accident rate. In view of the metal sector's importance and that the latest annual report (2019) reveals the sector to be among the ten sectors with Spain's highest accident rates, the purpose of this study is to explore the evolution of work accidents in the metal-mechanical sector in Spain for the period of 2009–2019 and to analyse the relationship between the associated variables. Data for this study come from occupational accident reports, which are required to be sent to the relevant administrative bodies using the Spanish Delt@ (electronic declaration of injured workers) computer system. The study variables were selected from the official occupational accident data and classified into four groups: personal, business, material, and time period. The relationships between severity and other variables were explored via contingency tables in which the chi-squared value ($\chi 2$) was calculated. This study shows a slight improvement in the accident rate over the last decade, but a high percentage of serious and fatal accidents in the Spanish industrial sector remains. The Monday effect, meal breaks, and being near retirement age are the most important factors influencing the number of serious accidents in this sector.

1. Introduction

Workplace accidents are one of the main problems confronting current production systems and modern society (Altunkaynak, 2018; Fidancı & Ozturk, 2015; Kifle et al., 2014; Takala et al. 2017). Occupational accidents involve minimally a great loss of working hours and productivity for companies and, in the worst cases, the loss of human lives with the consequent social cost (Cagno et al. 2011; ILO, 2015; NIHSW, 2007; Wang et al. 2018). Data about occupational accidents show part of the health damage suffered by workers and refer to both occupational accidents and occupational diseases (FUNDEA, 2015).

Accidents at work denote all physical injuries that workers suffer in association with paid work, meaning that accidents reflect the materialisation (with a degree of consequence) of exposure to a series of risks (European Union, 2011).

The investigation of work accidents is a safety technique with the purpose of discovering the causes of accidents. It is an essential first step in the design and implementation of appropriate preventive measures to avoid the occurrence of similar accidents (Anyfantis et al., 2021; Johnson & Holloway, 2003; Salguero-Caparros et al., 2015; Shao et al., 2019).

Research about occupational accidents in various sectors has identified the influence of personal characteristics such as age, experience, and skills (Carrillo-Castrillo et al., 2016; Chau et al., 2008; Reniers and

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Gidron, 2013; Salminen et al., 2008); the influence of variables associated with working conditions and environment (Chang and Tsai, 2014; Cheng et al., 2010); and the importance of analysing variables related to the consequences of these accidents, such as severity, type of injury, and the part of the body affected (Camino López et al., 2008; López-Arquillos et al., 2012; Zhang et al., 2020).

After analysing the scientific literature, Altunkaynak (2018) states that occupational accidents occur more frequently in the mining, industry, construction, and agriculture sectors. Within the industrial sector, one of the subsectors with the highest accident rate is the metal sector (Hedlund, 2013; Nenonen, 2011), which is also one of the subsectors in which workers are exposed to the worst and most dangerous working conditions (Díaz Aramburu et al., 2010).

The metal sector encompasses economic activities such as metallurgy and the manufacturing of metallic elements and includes production processes as diverse as the manufacturing of basic ferrous and nonferrous metal products, metal casting, material coating, and the manufacturing of tools and machinery.

Many of these production processes, regardless of each company's degree of automation, are highly manual, which means that worker-related characteristics are particularly important in the accident rate (Gulhan et al., 2012; Nenonen, 2011). One of these characteristics is age, with younger workers having a higher percentage of accidents, as shown in sectoral studies conducted in Spain (Díaz Aramburu et al., 2010) and Turkey (Gulhan et al., 2012). These results are also obtained in more specific studies, such as the one conducted by Batti-Gonçalves et al. (2018) in one of Brazil's major companies, where 62.5% of accidents involved workers aged 18–30. The age of workers is closely related to work experience, not only in the sector but also in the companies, with accident rates being higher in less experienced workers (Altunkaynak, 2018; Saha et al., 2007), although the severity of injuries and the duration of sick leave are higher among older workers (Díaz Aramburu et al., 2010; Jeong, 1999; Saha et al., 2007).

Other relevant characteristics to determine include the main causes of accidents and injuries, as these data can provide information to improve both the specific job and organisational aspects of the production process (Jo et al., 2017).

The most frequent causes of accidents in the metal sector identified in the scientific literature are falls, falling objects, and blows and cuts with materials and process machinery (Díaz Aramburu et al., 2010; Gulhan et al., 2012; Saha et al., 2007). The most frequent injuries are superficial injuries such as cuts and abrasions, followed by blows, dislocations, and sprains (Batti Gonçalves et al., 2018; Gulhan et al., 2012; Saha et al., 2007).

The construction and manufacturing sector has the highest incidence rate of occupational accidents. Barrera et al. (2021), in their study on occupational accidents in which a data mining technique was applied, common elements and differences were established. Among the differences is age, which varies depending on the injury. The study shows a similar behaviour in relation to time variables.

A study of the situational circumstances related to occupational accident rates in Spain's metal sector is justified for three reasons. First, the III Metal Sector Agreement (Spain, 2019) established a period of four years (from 1 October 2017 and at the rate of a quarter of their workforce per year) to achieve minimum training in health and safety for all workers in the metal sector, as well as basic-level training (50 h) for all prevention delegates. Given the proximity of this date and the fact that the reality of companies is far from the proposed objective, the results of this study can help to create and/or improve training plans, in accordance with the characteristics of the workers, type of company, and working hours, among other aspects.

Second, international and national authorities in occupational health and safety have determined the importance and need for research on new and emergent risks (NER) and their inclusion in new prevention models (OIT, 2010; Rial-González et al., 2005; Savolainen and Sas, 2006). In Spain, one of the objectives of the Spanish Strategy for Occupational Safety and Health in the period 2015–2020 (NIHSW, 2015) is research, development and innovation with the purpose of gaining knowledge about, identifying, and preventing new and emerging occupational risks. This study can allow us to identify NER in the metal sector to subsequently conduct more in-depth specific analyses that lead to the establishment of specific corrective and preventive measures.

Lastly, the accident rate in the metal sector has not been studied since 2009 (Díaz Aramburu et al., 2010). It is necessary to know the accident rate's evolution and current situation after the Spanish economic crisis between 2008 and 2014 and the measures adopted by the Spanish authorities in the field of occupational risk prevention, as the latest annual report (2019) reveals that the metal sector is among the ten sectors with Spain's highest accident rate (MEYSSS, 2019).

The main purposes of this study were to identify changes in work accidents over time and to analyse the relationship between the variables associated with accidents in the metal sector. The study analyses the occupational accident rate in Spain's metal sector and its changes over time, according to the factors associated with accidents. The results of this study could provide employers, workers, legislators, prevention technicians, and researchers with useful information for proposing organisational, technical, and regulatory improvements to reduce the metal sector's accident rate and thus limit social and economic impact of accidents.

The rest of the article is structured as follows. Section 2 describes the methodology. The results and comparisons with similar studies are presented in Section 3, and lastly, Section 4 shows the conclusions of our research.

2. Materials and method

2.1. Scope

The study focuses on the analysis of the accident rate in the Spanish metal sector between 2009 and 2019. The most recent study on accidents in the sector was presented in 2009, and 2019 is the year with the most published statistical data.

The metal sector is classified under codes 24 and 25 of the National Classification of all Economic Activities (CNAE, 2009), which is similar to the coding used by the European classification of economic activities (NACE). These codes are divided into the following subcodes that have been analysed in this work:

24: Metallurgy; Manufacturing of iron, steel, and ferro-alloy products

- 241: Manufacturing of basic iron, steel, and ferro-alloy products
- 242: Manufacturing of tubes, pipes, hollow profiles, and tube or pipe fittings of steel
- 243: Manufacturing of other primary steel processing products
- 244: Manufacturing of precious and other nonferrous metal products metals
- 245: Casting of metals

25: Manufacturing of fabricated metal products, except machinery and equipment

- 251 Manufacturing of fabricated metal products for construction
- 252 Manufacturing of tanks, reservoirs, and containers of metal
- 253 Manufacturing of steam generators, except central heating boilers
- 254 Manufacturing of weapons and ammunition
- 255 Forging, stamping, and pressing of metals; powder metallurgy
- 256 Treatment and coating of metals; mechanical engineering for others
- 257 Manufacturing of cutlery, tools, and hardware
- 259 Manufacturing of other fabricated metal products

2.2. Accident data

The data for this analysis are based on accidents that led to sick leave and occurred during working hours in the metal sector during the 2009–2019 period. This data comes from occupational accident reports, which are required to be sent to the relevant administrative body via the Delt@ (Electronic declaration of injured workers) IT system. In Spain, the information provided in occupational accident reports is structured in accordance with Act TAS/2926, 21 November 2002 (MLSAS, 2002). The purpose of this national standard is to implement guidelines from the Directive 89/391/EEC Council of the European Communities (European Union, 1989) to ensure the uniform processing of all data related to occupational accidents in EU member states. In our analysis, accidents to and from home to the workplace (which are considered work-related accidents in Spain) were considered.

In the accident reports, the severity of the accidents is classified as light, serious, and very serious. Additionally, fatal accidents are identified by the medical services of the mutual insurance companies. Accidents are defined as light when the resulting injuries are not expected to leave any aftereffects. If the injuries do not endanger the worker's life or if the aftereffects are not expected to disable, accidents are considered to be serious. Very serious accidents are determined when the consequences of the resulting injuries may cause permanent functional or organic alterations (disabling sequelae) or endanger the worker's life. If the worker dies, the accident is considered fatal.

2.3. Analysis design

The design of this analysis is based on methodologies used in previous research on accidents in the construction sector (Camino López et al., 2008; Forteza et al., 2017; López-Arquillos, 2012), electrical accidents in the construction sector (Suárez-Cebador et al., 2014), in the Andalusian (Spain) public universities (Suárez-Cebador et al., 2015), and in the mining sector (Sanmiquel et al., 2015). The metal sector comprises diverse jobs, from metallurgy to the manufacturing of various types of metal products, including tanks, tools, ironmongery, construction parts, or other assembly systems.

The data analysis has been divided into two steps. The first step presents a descriptive analysis of the metal sector's accident rate according to different variables, such as the period of the study and the Spanish regional state where the accident occurred. The second step consists of analysing the influence on the accident severity of a series of variables, which are collected in the notification reports of work accidents and have been used in previous research conducted in other industrial sectors (Camino López et al., 2008; López-Arquillos et al., 2012; Suárez-Cebador et al., 2014; Suárez-Cebador et al., 2015).

2.4. Study variables

The study variables were selected from the official occupational accident forms according to similar studies (Camino López et al., 2008; López-Arquillos et al., 2012; Suárez-Cebador et al., 2014; Suárez-Cebador et al., 2015) and classified into four groups according to the classification proposed by Camino-López et al. (2008). These groups are personal, business, material, and time periods (Table 1).

- Personal variables describe characteristics of the worker involved in the accident. The age variable is included.
- Business variables describe aspects about the activity and its organisation. Included are National Classification of Economic Activities (CNAE), company staff, length of service, and the accident's location.
- Temporal variables include day of the week, time of day, time of the working day and days of absence.
- Material variables include an unexpected deviation from accepted practice and injury.

Table 1
Summary of variables.

Variable group	Variable
Personal	Age
Business	CNAE
	Company staff
	Length service
	Location of accident
Temporal	Day of the week
	Time of day
	Time of the working day
	Days of absence
Material	Deviation
	Injury

2.5. Statistical analysis

Contingency tables and multifactor analysis of variance (ANOVA) were applied to detect and measure the strength of dependence between variables.

The study of the relationship between severity and the other variables was performed using contingency tables in which the value of the chi-squared statistic (χ^2) was calculated to test the hypothesis of the independence of severity with respect to the variables. This statistic shows the possible influence of the variables on severity. The corrected standardised residuals (csr) are calculated. When their absolute value is less than 1.96, which does not reach a statistical significance of 95%, the hypothesis of independence of variables is rejected. Absolute values of csr that are greater than 1.96 could confirm the existence besides a random influence for severity-related variables.

The total, fatal, very serious, and serious accident rates are determined and expressed in percentages. The total accident rate (TAR) was obtained by dividing the number of total accidents in the sector by the number of total accidents. The light accident rate (LAR) was obtained by dividing the number of light accidents in the sector by the number of total light accidents. The serious accident rate (SAR) was obtained by dividing the number of serious accidents in the sector by the number of total serious accidents. The very serious accident rate (VSAR) was obtained by dividing the number of very serious accidents in the sector by the total number of very serious accidents. Lastly, the fatal accident rate (FAR) was obtained by dividing the number of fatal accidents in the sector by the total number of fatal accidents.

Multifactor analysis of variance (multifactor ANOVA) was also performed to identify significant factors affecting the severity of accidents at the 95% level of confidence. The severity variable was selected as the response (dependent) variable, and the variables in Table 1 were selected as explanatory (independent) variables.

Importantly, the data studied are only about accidents that have occurred. Rates obtained in this study are not the typical incidence rates (number of accidents per number of workers at risk) because data about workers at risk in each category are not available.

All analyses were performed using the SPSS statistical analysis package.

3. Results and discussion

3.1. Descriptive analysis

A total of 35,627 accidents that caused sick leave occurred in 2009 in the Spanish metal sector during the working day. This figure dropped considerably to 18,677 accidents by 2013 (a 48% reduction), coinciding with a decrease in activity caused by the economic crisis (economic activity in 2013 was similar to 2009, consisting of €55,66 billion compared to €54,60 billion (NSE, 2021a)), and actions had been taken to improve occupational risk prevention (NIHSW, 2007). Data from 2009 to 2019 show a decrease in the number of total accidents by 21.96%.

This value could reflect the effectiveness of the pro-safety policy (NIHSW, 2007; NIHSW, 2015). This result aligns with other studies conducted in the production sector of EU countries from 2008 to 2018 (Nowackir, 2021).

Due to the upturn in activity in the sector, from 2013 to 2019, the number of accidents increased, reaching 27,804 accidents in 2019 (Fig. 1). The same increase occurred in other Spanish productive sectors (Fernández-Muñiz et al., 2018). This increase in the metal sector could be related to the implementation of Industry 4.0 (Nowackir, 2021).

Despite the slight growth in the metal sector's number of accidents, the number of serious and very serious accidents (Fig. 2) and the number of fatal accidents (Fig. 3) remained high and nearly unchanged during the study period. Table 2 shows the SAR + VSAR and FAR of the metal sector compared to that of the industrial sector and shows that serious and very serious accidents in the metal sector range between 21% and 24% of those in the industrial sector. In the proportion of fatal accidents, the oscillation is wider (13.5% and 33.6%) and reflects the death of more than an average of 20 people annually.

The metal sector has mostly male employees. According to National Statistical Institute (NSE) data (2021b), in 2019, the metal sector (codes 24 and 25) employed 324,700 workers, of which 44,700 were women (13.8%) and 280,000 were men (86.2%). If we analyse the results of accidents in the entire historical series, of the 275,294 accidents resulting in sick leave, 95.3% of TAR correspond to males and 4.7% to females. In the case of fatal accidents (FAR), the percentage of fatalities among men reaches 97.4%. These data can also be seen in other countries (Bakhtiyari et al. 2012). These results, which could be more deeply analysed if data were available on the positions held by men and women in the metal sector, reflect the need for specific information and training campaigns on occupational risk prevention for male workers in the metal sector.

Another aspect is the distribution of accidents (and their severity) according to Spanish autonomous communities. Spain is composed of 17 autonomous communities and two autonomous cities (Ceuta and Melilla). The autonomous communities are divided into provinces, with several autonomous communities having a single province and others having several provinces. According to the turnover in the industrial sector (NSE, 2021c), the autonomous communities with the highest turnover are Catalonia, Andalusia, Valencia, Madrid, the Basque Country, and Galicia. Since there are no public data on economic activity by national economic activity classifications (CNAE in Spanish) subcodes or employment data by CNAE subcodes, higher turnover assumedly shows a larger number of workers and, thus, greater exposure during the working day to occupational hazards, resulting in a higher accident rate.

Table 3 shows the accidents in the metal sector by autonomous communities and severity. The autonomous communities with the highest TAR are Basque Country, Catalonia and Andalusia, with accident rates above 10% in the sector in the study period. These autonomous communities are similarly represented in the LAR, SAR, VSAR and FAR groups and are among the regions with the highest turnover in the industrial sector. Notably, regardless of the volume of business conducted, the Balearic Islands and the cities of Ceuta and Melilla had no fatal accidents in the 11 years that comprise the study period.

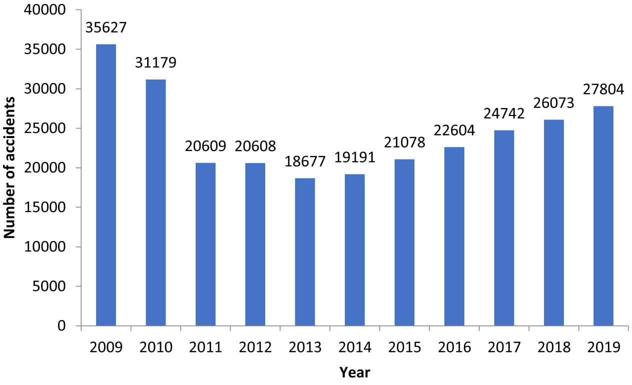


Fig. 1. Trend of the total number of accidents (2009–2019).

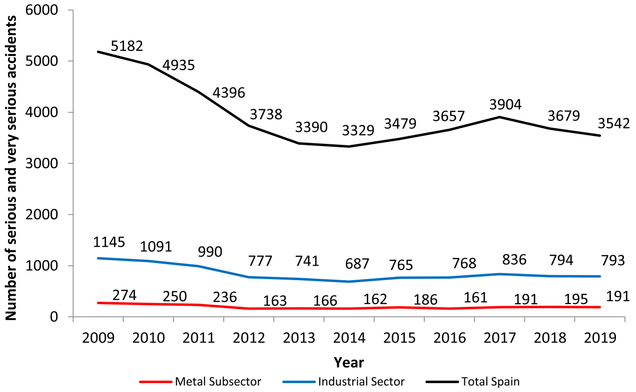


Fig. 2. Trend in the number of serious and very serious accidents (2009–2019).

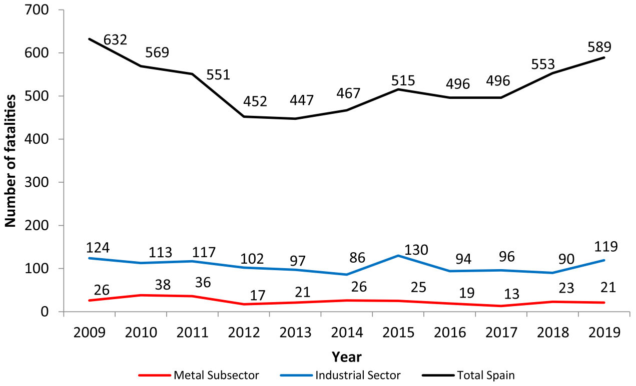


Fig. 3. Trend in the number of fatal accidents (2009–2019).

Table 2
Comparison of serious, very serious, and fatal accidents between the metal sector and industrial sector (2009–2019).

YEAR	SAR + VSAR METAL/SAR + VSAR INDUSTRIAL SECTOR (%)	FAR METAL/FAR INDUSTRIAL SECTOR (%)
2009	23.9	21.0
2010	22.9	33.6
2011	23.8	30.8
2012	21.0	16.7
2013	22.4	21.7
2014	23.6	30.2
2015	24.3	19.2
2016	21.0	20.2
2017	22.9	13.5
2018	24.6	25.6
2019	24.1	17.7

Fig. 4 shows the TAR (%) by province, and Fig. 5 shows the FAR (%) by province. The province of Barcelona accounted for 14.8% of the total accident rate during the study period. After Barcelona, the provinces of Navarre, Asturias, Madrid, and the Basque Country had the highest accident rates. The highest fatal accident rates were in the provinces of Barcelona (11.7%) and Biscay (14.0%), and the increase was particularly significant when compared to the percentage of TAR for Bizkaia (9.4%). The provinces of Almería, Ávila, Baleares, Cáceres, Guadalajara, Palencia, Salamanca, Segovia, Teruel and the cities of Ceuta and Melilla had no fatal accidents in the study period.

The results for the different autonomous communities have also been

Table 3
Accidents in the metal sector by autonomous communities and severity.

Autonomous communities	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
Andalusia	28,527	10.4	28,206	10.3	279	13.4	14	16.3	28	10.6
Aragon	9,537	3.5	9,470	3.5	58	2.8	4	4.7	5	1.9
Asturias	15,656	5.7	15,530	5.7	103	4.9	4	4.7	19	7.2
Baleares	2,532	0.9	2,516	0.9	15	0.7	1	1.2	0	0.0
Canarias	2,482	0.9	2,446	0.9	30	1.4	2	2.3	4	1.5
Cantabria	6,042	2.2	5,971	2.2	57	2.7	2	2.3	12	4.5
Catalonia	51,844	18.8	51,394	18.8	389	18.6	18	20.9	43	16.2
Castille Leon	14,027	5.1	13,895	5.1	112	5.4	6	7.0	14	5.3
Castille La Mancha	12,044	4.4	11,940	4.4	89	4.3	2	2.3	13	4.9
Valencia	13,965	5.1	13,815	5.1	128	6.1	1	1.2	21	7.9
Extremadura	3,973	1.4	3,914	1.4	57	2.7	1	1.2	1	0.4
Galicia	17,844	6.5	17,587	6.4	231	11.1	7	8.1	19	7.2
La Rioja	2,306	0.8	2,283	0.8	19	0.9	1	1.2	3	1.1
Madrid	21,081	7.7	20,965	7.7	99	4.7	4	4.7	13	4.9
Murcia	5,802	2.1	5,755	2.1	39	1.9	5	5.8	3	1.1
Navarre	9,451	3.4	9,365	3.4	74	3.5	4	4.7	8	3.0
Basque Country	58,084	21.1	57,705	21.1	310	14.8	10	11.6	59	22.3
Ceuta	31	0.0	31	0.0	0	0.0	0	0.0	0	0.0
Melilla	66	0.0	66	0.0	0	0.0	0	0.0	0	0.0

TAR: number of accidents/total number accidents (%).
LAR: number of light accidents/total number light accidents (%).
SAR: number of serious accidents/total number serious accidents (%).
VSAR: number of very serious accidents/total number very serious accidents (%).
FAR: number of fatal accidents/total number fatal accidents (%).

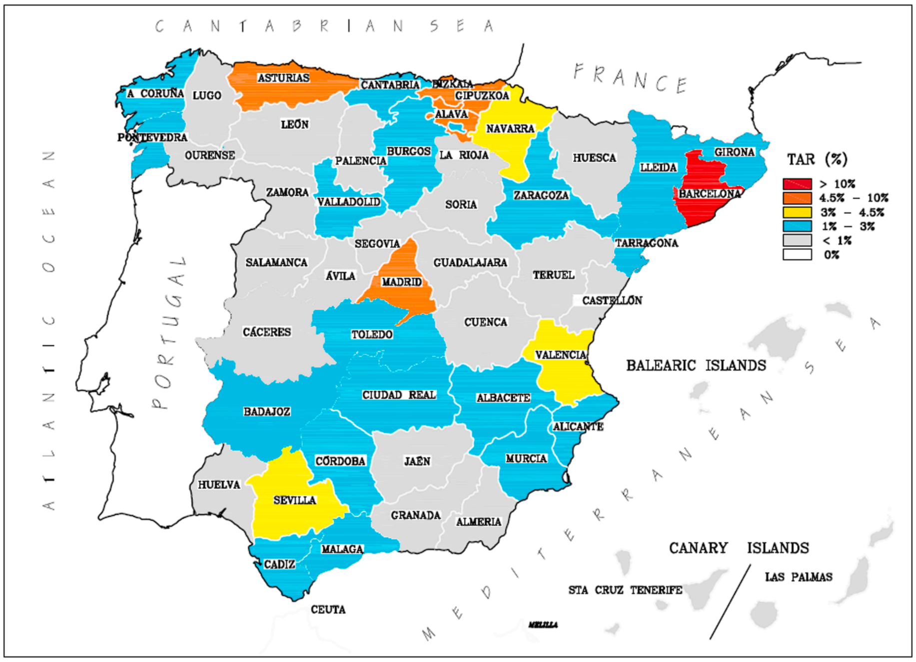


Fig. 4. Total accident rate (TAR %) in the metal sector by province.

found in studies of the production sector in EU countries in which the researcher relates the number of accidents and the employed population (Nowackir, 2021).

3.2. Relationship between variables associated with the accidents

Fig. 6 shows the results of a correlation analysis for the study variables considered (Table 1). Deviation and company staff are strongly correlated. The correlation between the other variables is medium, weak or very weak.

The following sections show the χ^2 contingency table analyses to address the relationships between the study variables and accident severity.

3.2.1. Personal variables

3.2.1.1. Age. The analysis of the contingency table for the worker's age and severity variables indicates a dependent relationship between accident severity and worker's age (Pearson Chi-Square statistic, $\chi^2 =$ 230.897, and $p < 0.001$; Somers D coefficient = −0,0630) (Table 4). The Somers D coefficient shows a low negative association. Only 8 corrected standardised residuals (25.00%) were significant at the 95% confidence

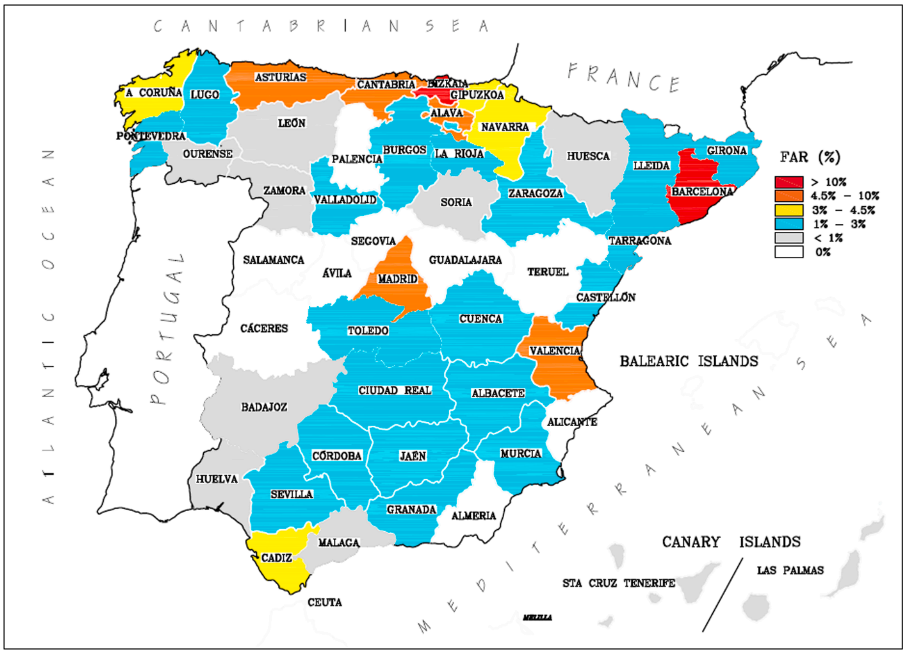
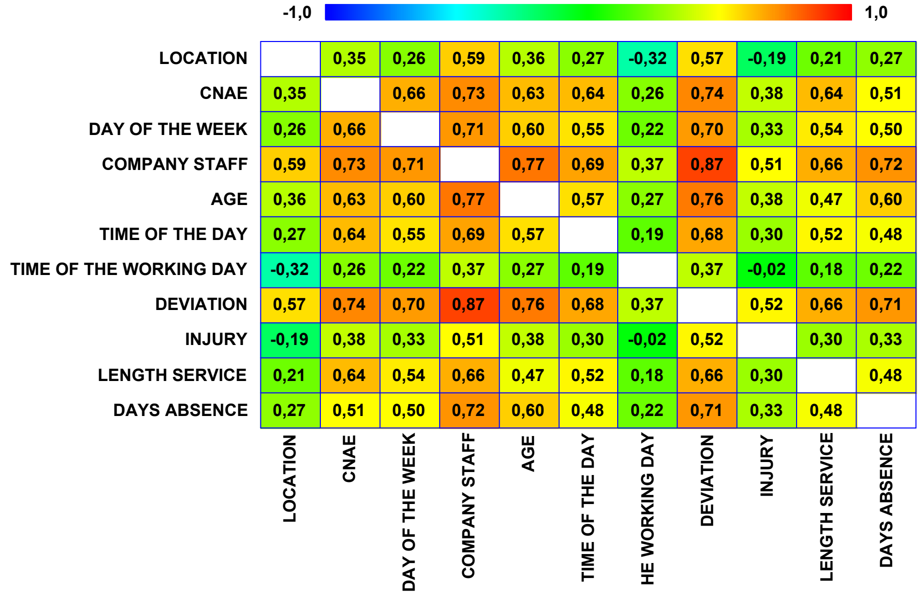


Fig. 5. Fatal accidents rate (FAR %) in the metal sector by province.



	LOCATION	CNAE	DAY OF THE WEEK	COMPANY STAFF	AGE	TIME OF THE DAY	HE WORKING DAY	DEVIATION	INJURY	LENGTH SERVICE	DAYS ABSENCE
LOCATION		0,35	0,26	0,59	0,36	0,27	-0,32	0,57	-0,19	0,21	0,27
CNAE	0,35		0,66	0,73	0,63	0,64	0,26	0,74	0,38	0,64	0,51
DAY OF THE WEEK	0,26	0,66		0,71	0,60	0,55	0,22	0,70	0,33	0,54	0,50
COMPANY STAFF	0,59	0,73	0,71		0,77	0,69	0,37	0,87	0,51	0,66	0,72
AGE	0,36	0,63	0,60	0,77		0,57	0,27	0,76	0,38	0,47	0,60
TIME OF THE DAY	0,27	0,64	0,55	0,69	0,57		0,19	0,68	0,30	0,52	0,48
TIME OF THE WORKING DAY	-0,32	0,26	0,22	0,37	0,27	0,19		0,37	-0,02	0,18	0,22
DEVIATION	0,57	0,74	0,70	0,87	0,76	0,68	0,37		0,52	0,66	0,71
INJURY	-0,19	0,38	0,33	0,51	0,38	0,30	-0,02	0,52		0,30	0,33
LENGTH SERVICE	0,21	0,64	0,54	0,66	0,47	0,52	0,18	0,66	0,30		0,48
DAYS ABSENCE	0,27	0,51	0,50	0,72	0,60	0,48	0,22	0,71	0,33	0,48	

Fig. 6. Diagram of correlation for the study variables considered: Correlation maps (Spearman correlation coefficient). X = p value no significant difference at a 5% significance level.

level (p > 1.96). Based on these results, age and severity are related, but age cannot be clearly considered to predict severity.

Age-Severity distribution is not uniform. The age ranges with the highest accident rates are between 30 and 39 (TAR 33.1%) and 40 and 49 (TAR 27.9%). The results from other studies in the metal sector indicate that younger workers have a higher accident rate (Chang and Tsai, 2014; López-Arquillos et al., 2012). A systematic literature review of occupational safety and health among young workers in Nordic countries denotes unskilled workers and young skilled workers as vulnerable to accidents. Their results suggest for leaders and workers to focus on the OSH culture in workplaces, as the behaviour of leaders and workers on a day-to-day basis sets the standard that young workers follow (Hanvold et al., 2019).

Notably, the highest number of fatal accidents occurs in the age range of 50–59 (FAR 36.2%), with percentages much higher than the values of LAR, SAR, and VSAR for that age range (17.4%, 23.4% and 25.6%, respectively). In alignment with a study in the UK (Farrow and Reynolds, 2012), the age range of 60–59 has a low association with fatal accidents.

These data can be a basis for developing sectoral and/or company policies with the purpose of limiting the accident rate of workers in this age group (and the immediately higher age group up to retirement age) with measures such as shorter working hours and a combination of administrative, control, and/or sorting and cleaning tasks. Age-related changes in workers require special attention (Varianou-Mikellidou et al., 2019).

Table 4
Accidents in the metal industry by age and severity.

Chi-square 230.897 df = 21 Sig. < 0.001

Age (years)	Total accidents		Light		Serious		Very Serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
16–19	2,668	1.0	2,637	1.0*	28	1.3*	1	1.2*	2	0.8*
20–24	16,918	6.1	16,801	6.2*	103	4.9	3	3.5*	11	4.2*
25–29	31,070	11.3	30,870	11.3*	174	8.3	9	10.5*	17	6.4
30–39	91,117	33.1	90,482	33.2*	562	26.9	19	22.1*	54	20.4
40–49	76,917	27.9	76,204	27.9*	618	29.6*	28	32.6*	67	25.3*
50–59	48,142	17.5	47,535	17.4*	489	23.4	22	25.6*	96	36.2
60–69	8,432	3.1	8,296	3.0*	114	5.5	4	4.7*	18	6.8
> 70	30	0.0	29	0.0*	1	0.0*	0	0.0*	0	0.0*

* : Corrected standardised residuals < 1.96 in absolute value.

3.2.2. *Business variables*

3.2.2.1. CNAE. Organisational activity is one factor to be considered when analysing accidents in an economic sector such as the metal sector. As indicated in Section 2.1, the metal sector is divided into two groups, which are then divided into 13 subgroups. Table 5 shows the analysis between CNAE and severity.

The analysis of the contingency table for the CNAE and severity variables indicates a dependent relationship between severe accidents and CNAEs (Pearson chi-square statistic, $\chi^2 = 135.330$, and $p < 0.001$; Someŕs D coefficient = 0,0014) (Table 5. Someŕs D coefficient shows a low association. Only 7 corrected standardised residuals (13.46%) were significant at the 95% confidence level ($p > 1.96$). Based on these results, CNAEs and severity are related, but CNAEs cannot be clearly considered to predict severity.

CNAE-Severity distribution is not uniform. The activity with the highest accident rate is *251-Manufacturing of fabricated metal products for construction* (TAR 29.1%, LAR 29.1%, SAR 34.3%, VSAR 34.9%, FAR 23.0%) followed by activity *256-Treatment and coating of metals; mechanical engineering for others* (TAR 16.6%, LAR 16.7%, SAR 13.2%, VSAR 11.6%, FAR 14.3).

Significantly, activity *241-Manufacturing of basic iron, steel and ferro-alloy products* has only 6.7% of the total accidents (TAR) in the sector, but the percentage of fatal accidents (FAR) is 15.8%.

3.2.2.2. Company staff. The analysis of the contingency table for the company staff and severity variables indicates a dependent relationship between accident severity and company staff (Pearson chi-square statistic, $\chi 2 = 153.888$, and $p < 0.001$; Someŕs D coefficient = 0,0235) (Table 6). Someŕs D coefficient shows a low association. Only 6 corrected standardised residuals (21.43%) were significant at the 95% confidence level ($p > 1.96$). Based on these results, company staff and severity are related and more highly associated than CNAE severity, but company staff cannot be clearly considered to predict severity.

Company staff-Severity distribution is not uniform. A greater number of accidents occurs in companies with between 11 and 25 workers (20.2%) and in companies with between 26 and 50 workers (18.2%), but calculating the percentage of fatal accidents with respect to the total number of accidents (FAR/TAR) occurring by company size (Table 7) shows that a greater number of fatal accidents occurs in companies with more than 250 workers (0.17%), followed by companies with between 100 and 250 workers (0.1189%). These results are similar to other studies in Spain's construction sector (Chang and Tsai, 2014; Camino López et al., 2008; Forteza et al., 2017) and contrasts with other studies that relate company size to better safety practices (Fabiano et al., 2004; Fernández-Muñiz et al., 2018; Hinze and Gambatese, 2003).

3.2.2.3. Length of service. Length of employment with the company refers to the length of time the worker has been employed with a company and not his or her industry experience. This variable was analysed considering eight groups: workers with less than one month in the company and workers with more than 30 years of service in the company (Table 8).

Analysis of the contingency table for the length of service and severity variables indicates a dependent relationship between accident severity and company staff (Pearson chi-square statistic, $\chi 2 = 77.378$, and $p < 0.001$; Someŕs D coefficient = 0,0016) (Table 8). Only 6 corrected standardised residuals (18.75%) were significant at the 95%

Table 5
Accidents in the metal sector by CNAE and severity.

Chi-square 135.330 df = 36 Sig. < 0.001

CNAE	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
241	18,566	6.7	18,363	6.7*	157	7.5*	4	4.7*	42	15.8
242	5,148	1.9	5,094	1.9*	40	1.9*	2	2.3*	12	4.5
243	16,787	6.1	16,618	6.1*	141	6.7*	8	9.3*	20	7.5*
244	6,649	2.4	6,560	2.4*	72	3.4	4	4.7*	13	4.9
245	19,902	7.2	19,738	7.2*	144	6.9*	4	4.7*	16	6.0*
251	80,141	29.1	79,333	29.1*	717	34.3	30	34.9*	61	23.0*
252	13,785	5.0	13,697	5.0*	80	3.8	4	4.7*	4	1.5
253	557	0.2	555	0.2*	1	0.0*	0	0.0*	1	0.4*
254	940	0.3	935	0.3*	4	0.2*	0	0.0*	1	0.4*
255	27,702	10.1	27,486	10.1*	186	8.9*	10	11.6*	20	7.5*
256	45,804	16.6	45,481	16.7*	275	13.2	10	11.6*	38	14.3*
257	18,094	6.6	17,949	6.6*	121	5.8*	5	5.8*	19	7.2*
259	21,219	7.7	21,045	7.7*	151	7.2*	5	5.8*	18	6.8*

* : Corrected standardised residuals < 1.96 in absolute value.

Table 6
Accidents in the metal sector by companies and severity.

Chi-square 153.888 df = 18 Sig. < 0.001

Company staff (number of workers)	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
≤ 5	36,344	13.2	35,866	13.1*	417	20.0	24	27.9	37	14.0*
6–10	28,511	10.4	28,220	10.3*	251	12.0	12	14.0*	28	10.6*
11–25	55,603	20.2	55,144	20.2*	402	19.2*	17	19.8*	40	15.1*
26–50	50,042	18.2	49,666	18.2*	330	15.8	9	10.5*	37	14.0*
51–100	41,240	15.0	40,946	15.0*	254	12.2	7	8.1*	33	12.5*
100–250	35,322	12.8	35,055	12.8*	216	10.3	9	10.5*	42	15.8*
>250	28,232	10.3	27,957	10.2*	219	10.5*	8	9.3*	48	18.1

* : Corrected standardised residuals < 1.96 in absolute value.

Table 7
Percentages of fatal accidents with respect to total accidents by company size.

Company staff (number of workers)	Number of total accidents (NTA)	Number of fatal accidents (NFA)	% (NFA/NTA)
≤ 5	36,344	37	0.1018
6–10	28,511	28	0.0982
11–25	55,603	40	0.0719
26–50	50,042	37	0.0739
51–100	41,240	33	0.0800
100–250	35,322	42	0.1189
>250	28,232	48	0.1700

confidence level (p > 1.96). Based on these results, the length of employment and severity are related, but the length of employment cannot be clearly considered to predict severity.

Length of service-Severity distribution is not uniform. The number of accidents involving workers with less than one month of experience in the company reaches 10.5% TAR and 14.3% FAR. Carrillo-Castrillo et al. (2016) suggested that inappropriate work methods or a lack of adequate training were possible causes of this situation. Therefore, a more aggressive information policy and training in occupational safety at the start of work in a company should be required. López Arquillos et al. (2012) proposed calculating the TAR-FAR rates to analyse the differences by length of service. Fig. 7 shows that FAR is more important than TAR, not only in the group of recently hired workers but also in the groups with more seniority in the company (eleven years and older); therefore, it would be important to consider actions, such as training plans for recycling, in risk prevention, especially when new technologies are introduced that can create new and emerging risks (NER) (Brocal et al., 2017; Brocal et al., 2019; Brocal et al., 2021).

3.2.2.4. Accident location. Analysis of the contingency table for the accident's location and severity variables indicates that a dependent relationship between severe accidents and company staff (Pearson chi-square statistic, χ2 = 1,092.904, and p < 0.001; Someŕs D coefficient = −0,0763) (Table 9). Twelve corrected standardised residuals (75.00%) are significant at the 95% confidence level (p > 1.96). Based on these results, the accident's location and severity are related.

The accident location and severity distributions are not uniform. Safety in the workplace is one of the fundamental pillars of occupational risk prevention plans and policies. In the metal sector, most accidents occur in the workplace (89.9%), and unlike other sectors, such as construction (López-Arquillos et al., 2012), the number of accidents outside the workplace is not high (Table 9). Interestingly, the percentage of very serious and fatal accidents in the usual worksite drops considerably while the number of very serious and fatal accidents increases when travelling between worksites, in other worksites, and travelling to and from the worksite (VSAR 16.3% and FAR 20.4%).

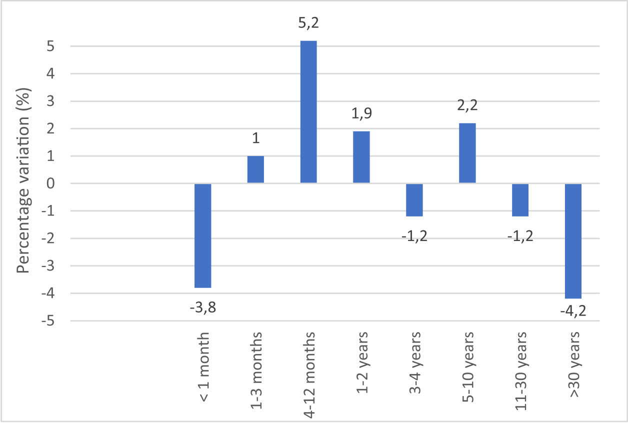


Fig. 7. Percentage variation of TAR-FAR (%) in length of service.

Table 8
Accidents in the metal sector by length service and severity.

Chi-square 77.378 df = 21 Sig. < 0.001

Length service	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
< 1 month	28,788	10.5	28,456	10.4*	278	13.3	16	18.6	38	14.3
1–3 months	17,449	6.3	17,298	6.3*	130	6.2*	7	8.1*	14	5.3*
4–12 months	39,377	14.3	39,040	14.3*	302	14.5*	11	12.8*	24	9.1
1–2 years	25,871	9.4	25,665	9.4*	178	8.5*	8	9.3*	20	7.5*
3–4 years	34,192	12.4	33,921	12.4*	227	10.9	8	9.3*	36	13.6*
5–10 years	60,047	21.8	59,589	21.8*	393	18.8	13	15.1*	52	19.6*
11–30 years	62,338	22.6	61,747	22.6*	508	24.3*	20	23.3*	63	23.8*
>30 years	7,232	2.6	7,138	2.6*	73	3.5	3	3.5*	18	6.8

* : Corrected standardised residuals < 1.96 in absolute value.

Table 9
Accidents in the metal sector by accident location and severity.

Chi-square 1,092.904 d.f. = 9 Sig. < 0.001

Accident location	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
Usual workplace	247,570	89.9	245,784	90.1*	1589	76.1	44	51.2	153	57.7
Moving between work areas	5,249	1.9	5,112	1.9*	93	4.5	12	14.0	32	12.1
Going to or coming from worksite	14,419	5.2	14,163	5.2*	188	9.0	14	16.3	54	20.4
Different workplace	8,056	2.9	7,795	2.9	219	10.5	16	18.6	26	9.8

* : Corrected standardised residuals < 1.96 in absolute value.

3.2.3. *Time variables*

3.2.3.1. Day of the week. The analysis of the contingency table for the day of the week and severity variables indicates a dependent relationship between accident severity and company staff (Pearson chi-square statistic, $\chi 2 = 62.128$, and $p < 0.001$; Somerś D coefficient = 0,0532) (Table 10). Only 2 corrected standardised residuals (7.14%) were significant at the 95% confidence level ($p > 1.96$). Based on these results, the accident location and severity are related, but the day of the week cannot be clearly considered to predict severity.

Table 10 shows that Monday has the most accidents. This phenomenon, called the 'Monday effect', is defined as the high number of occupational accidents reported on Mondays. Many of these accidents occur during the weekend and outside of work but are reported on Mondays to benefit from employer or workers' compensation insurance coverage. This phenomenon has been studied by Card and McCall (1996) and by Campolieti and Hyatt (2006) and is similar to other Spanish industrial sectors (Camino López et al., 2008; Carrillo-Castrillo et al., 2016; López-Arquillos et al., 2012). Some injuries reported on Monday occurred during the weekend and are reported on Monday because insurance companies compensate more for work-related injuries than for those that occur during leisure activities. The total number of accidents decreases as the week progresses. The FAR is similar from Monday to Wednesday (above 20.0%), but decreases on Thursdays and Fridays (15.8% and 15.1% FAR, respectively).

3.2.3.2. Time of day. The analysis of the contingency table for the time of day and severity variables indicates a dependent relationship between accident severity and time of day (Pearson Chi-Square statistic, $\chi 2 = 98.884$, and $p < 0.001$; Somerś D coefficient = −0,0016) (Table 10). Only 7 corrected standardised residuals (14.58%) were significant at the 95% confidence level ($p > 1.96$). Based on these results, the location of accident and severity are related, but the time of week cannot be clearly considered to predict severity.

The time of day and severity distribution are not uniform. Table 11 shows an analysis between the time of day and severity. The highest number of accidents in the metal sector are between 10:00 and 12:59 (33.5% TAR; 33.6% LAR; 29.3% SAR; 38.8% VSAR; 21.9% FAR). In addition, the time period between 11:00 and 11:59 shows the highest percentage of serious and fatal accidents (19.8% and 8.3% respectively). One possible explanation could be that this time period follows the workers' usual meal break (Suárez-Cebador et al., 2015).

In the period between 21:00 and 7:59, 16.9% of LAR, 17.1% of SAR, 14.0% of VSAR, and 25.7% of FAR occurred. These values could be due to fewer personnel working during night shifts, relaxation of health and safety measures, or greater operator fatigue. This aspect should be reviewed in company organisational measures and sectoral prevention policies.

3.2.3.3. Time of the working day. In addition to the previous subsection, the severity of accidents was analysed with the time of the working day. The analysis of the contingency table for time of the working day and severity variables indicates a dependent relationship between severity accident and time of the day (Pearson chi-square statistic, $\chi 2 = 178.315$, and $p = 0.001$; Somerś D coefficient = −0.0073) (Table 12). Only 6 corrected standardised residuals (12.58%) were significant at the 95% confidence level ($p > 1.96$). Based on these results, time of the working day and severity are related, but time of week cannot be clearly considered to predict severity.

The time of the working day and severity distribution were not uniform. The highest number of total, minor, and severe accidents occurred in the second hour of the working day (16.5% TAR; 16.5% LAR; 15.6% SAR), and the highest number of very severe and fatal accidents occurred in the third hour of the working day (17.4% VSAR and 12.8% FAR). Contrary to expectations and associated with workers' accumulated fatigue the number of light, serious, very serious, and total accidents decrease as the hours of the workday pass. This result can be found in other studies (Backkonsnala, 2007; Hänecke et al., 1998)

3.2.3.4. Days of absence. The analysis of the contingency table for days of absence and severity variables indicates a dependent relationship between severity accident and time of the day (Pearson chi-square statistic, $\chi 2 = 205{,}821.285$, and $p = 0.001$; Somerś D coefficient = −0.1950) (Table 13). A total of 23 corrected standardised residuals

Table 10
Accidents in the metal sector by day of the week and severity.

Chi-square 62.128, df = 18 Sig. < 0.001

Day of the week	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
Monday	59,933	21.8	59,469	21.8*	390	18.7	21	24.4*	53	20.0*
Tuesday	57,675	21.0	57,189	21.0*	413	19.8*	18	20.9*	55	20.8*
Wednesday	54,228	19.7	53,767	19.7*	383	18.3*	17	19.8*	61	23.0*
Thursday	48,944	17.8	48,484	17.8*	405	19.4*	13	15.1*	42	15.8*
Friday	42,111	15.3	41,713	15.3*	347	16.6*	11	12.8*	40	15.1*
Saturday	9,251	3.4	9,115	3.3*	121	5.8	4	4.7*	11	4.2*
Sunday	3,152	1.1	3,117	1.1*	30	1.4*	2	2.3*	3	1.1*

* : Corrected standardised residuals < 1.96 in absolute value.

Table 11
Accidents in the metal sector by time period and severity.

Chi-square 98.884 df = 39 Sig. < 0.001

Day time	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
From 8:00 to 8:59	17,763	6.5	17,598	6.4*	139	6.7*	5	5.8*	21	7.9*
From 9:00 to 9:59	21,467	7.8	21,293	7.8*	157	7.5*	8	9.3*	9	3.4
From 10:00 to 10:59	32,659	11.9	32,446	11.9*	190	9.1	8	9.3*	15	5.7
From 11:00 to 11:59	28,513	10.4	28,262	10.4*	212	10.1*	17	19.8	22	8.3*
From 12:00 to 12:59	30,949	11.2	30,711	11.3*	210	10.1*	7	8.1*	21	7.9*
From 13:00 to 13:59	17,140	6.2	16,973	6.2*	142	6.8*	9	10.5*	16	6.0*
From 14:00 to 14:59	11,491	4.2	11,383	4.2*	86	4.1*	4	4.7*	18	6.8
From 15:00 to 15:59	11,639	4.2	11,516	4.2*	108	5.2	0	0.0*	15	5.7*
From 16:00 to 16:59	16,905	6.1	16,733	6.1*	151	7.2	3	3.5*	18	6.8*
From 17:00 to 17:59	17,375	6.3	17,211	6.3*	139	6.7*	5	5.8*	20	7.5*
From 18:00 to 18:59	11,836	4.3	11,721	4.3*	106	5.1*	1	1.2*	8	3.0*
From 19:00 to 19:59	6,222	2.3	6,151	2.3*	61	2.9	3	3.5*	7	2.6*
From 20:00 to 20:59	4,840	1.8	4,799	1.8*	30	1.4*	4	4.7	7	2.6*
Rest of hours	46,495	16.9	46,057	16.9*	358	17.1*	12	14.0*	68	25.7

* : Corrected standardised residuals < 1.96 in absolute value.

Table 12
Accidents in the metal sector by time of the working day and severity.

Chi-square 178.315 d.f. = 33 Sig. = 0.001

Time of the working day	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	TAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
0	9,147	3.3	9,012	3.3*	97	4.6	11	12.8	27	10.2
1	31,387	11.4	31,102	11.4*	255	12.2*	6	7.0*	24	9.1*
2	45,253	16.5	44,887	16.5*	326	15.6*	14	16.3*	26	9.8
3	39,944	14.5	39,628	14.5*	267	12.8	15	17.4*	34	12.8*
4	38,624	14.0	38,320	14.0*	271	13.0*	9	10.5*	24	9.1
5	27,820	10.1	27,588	10.1*	198	9.5*	9	10.5*	25	9.4*
6	28,284	10.3	28,043	10.3*	205	9.8*	8	9.3*	28	10.6*
7	25,383	9.2	25,157	9.2*	193	9.2*	7	8.1*	26	9.8*
8	15,824	5.7	15,677	5.7*	129	6.2*	1	1.2*	17	6.4*
9	1,981	0.7	1,960	0.7*	17	0.8*	1	1.2*	3	1.1*
10	1,800	0.7	1,788	0.7*	11	0.5*	0	0.0*	1	0.4*
>10	9,847	3.6	9,692	3.6*	120	5.7	5	5.8*	30	11.3

* : Corrected standardised residuals < 1.96 in absolute value.

(71.88%) are significant at the 95% confidence level ($p > 1.96$). Based on these results, the time of the working day and severity are related.

Accidents in the metal sector mostly result in between 2 and 7 days of sick leave (25.3%) and 8 and 15 days of sick leave (25.6%). Remarkably, most deaths occur at the time of the accident (73.2%) or within a week (15.8%). In only 29 cases of the 265 do deaths not occur within that period. The second noteworthy point is that severe and very severe accidents result in absences of between 7 and 12 months (38.1% and 40.7%).

3.2.4. *Material variables*

3.2.4.1. Deviation. The analysis of the contingency table for the deviation and severity variables indicates a dependent relationship between accident severity and deviation (Pearson Chi-Square statistic, $\chi2 = 1,576.666$, and $p < 0.001$; Someŕs D coefficient = 0.1174) (Table 14). Someŕs D coefficient shows a low association. A total of 20 Corrected standardised residuals (55.56%) are significant at the 95% confidence level ($p > 1.96$). Based on these results, deviation and severity are

Table 13
Accidents in the metal sector by days of absence and severity.

Chi-square 205,821.285 df = 21 Sig. < 0.001

Absence	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
1 day	214	0.1	19	0	0	0*	1	1.3	194	73.2
2–7 days	69,740	25.3	69,662	25.5	29	1.4	7	8.1	42	15.8
8–15 days	70,501	25.6	70,459	25.8	35	1.7	3	3.5	4	1.5
16–30 days	50,646	18.4	50,605	18.5*	37	1.8	2	3.5	1	0.4
1–3 months	42,945	15.6	42,621	15.6*	316	15.1*	7	8.1*	1	0.4
4–6 months	10,413	3.8	9,766	3.6	630	30.2	17	19.8	0	0.0
7–12 months	4,510	1.6	3,679	1.3	796	38.1	35	40.7	0	0.0
>1 year	26,325	9.6	26,043	9.5*	246	11.8	13	15.1*	23	8.7*

* : Corrected standardised residuals < 1.96 in absolute value.

Table 14
Accidents in the metal sector by deviation and severity.

Chi-square 1,576.666 df = 24 Sig. < 0.000

Deviation	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
Electricity, explosion, fire	2,533	0.9	2,466	0.9*	55	2.6	3	3.5*	9	3.4
Falling object	12,424	4.5	12,356	4.5*	62	3.0	5	5.8	1	0.4
Fall, slide	22,651	8.2	22,277	8.2*	332	15.9	10	11.6*	32	12.1
Loss of machine control	73,791	26.8	72,976	26.7*	683	32.7	32	37.2*	100	37.7
Falls involving people	25,541	9.3	25,075	9.2*	425	20.3	22	25.6	19	7.2*
Voluntary body movement	53,095	19.3	52,807	19.4*	265	12.7	4	4.7	19	7.2
Involuntary body movement	70,452	25.6	70,358	25.8	91	4.4	1	1.2	2	0.8
Shock or jolting action	1,181	0.4	1,151	0.4*	28	1.3	1	1.2*	1	0.4*
No information	13,626	4.9	13,388	4.9*	148	7.1	8	9.3*	82	30.9

* : Corrected standardised residuals < 1.96 in absolute value.

related.

The metal sector encompasses highly manual activities and other activities involving a continuous use of machinery, leading to accidents caused by loss of control over machinery (26.8%), involuntary body movement (25.6%) and voluntary body movement (19.3%) (Table 14). These results align with those in other studies (Díaz Aramburu et al. 2010; Gulhan et al., 2012; Hedlund, 2013). Some of the accidents, such as falls to the same or different level and falls involving objects, can occur in the metal and other sectors, as seen in the database consulted and in other studies (Khahro et al., 2020; Laschi et al., 2016; Shimizu et al., 2021). More important are the results regarding very serious and fatal accidents in which approximately 4 out of 10 accidents are caused by loss of control over machinery. These results call for further training of workers in machine operation and machine safety systems (Carrillo-Castrillo et al., 2016) and improvement in OHS management systems (Fernández-Muñiz et al., 2018).

3.2.4.2. Injury. The analysis of the contingency table for injury and severity variables indicates a dependent relationship between accident severity and injury (Pearson chi-square statistic, $\chi2 = 43,422.569$, and $p < 0.001$; Someŕs D coefficient = −0.3172) (Table 15). A total of 33 Corrected standardised residuals (51.56%) are significant at the 95% confidence level ($p > 1.96$). Based on these results, injury and severity are related.

Amputations, crushed bones, concussions and internal injuries are related to mainly severe, very severe or fatal accidents in the metal sector. In the Spanish metal sector, dislocations, sprains and strains, wounds and superficial injuries are involved in 81.2% of TAR (Table 15), which is confirmed by another study conducted in the sector (Díaz Aramburu et al. 2010; Gulhan et al., 2012; Hedlund, 2013, Batti Gonçalves et al., 2018; Gulhan et al., 2012; Saha et al., 2007). In contrast, these types of injuries negligibly impact fatal accidents (0.4% FAR). The most dangerous injuries involve concussions and internal injuries, multiple lesions, heart attacks, strokes, and other nontraumatic diseases. Special attention should be given to the group ‘multiple lesions’ (0.9% of TAR but 40.4% of FAR) and the group ‘heart attacks, strokes, and other nontraumatic diseases’ (0.1% of TAR and 31.7% of FAR). This also occurs in other sectors, such as construction (López-Arquillos et al., 2012). Improving this situation requires training workers in first-aid for initial care of the injured workers until the emergency services arrive, as well as including the mandatory availability of defibrillators in workplaces.

Data were subjected to a multifactor analysis of variance (ANOVA) to compare with the results of the χ2 contingency table analyses. The analysis was performed for the variables in Table 1 and accident severity to determine which of the variables were significant in the severity of accidents at the 95% confidence level. The age variable has 8 levels (see the first column of Table 4), the CNAE has 12 levels (see the first column of Table 5), company staff has 7 levels (see the first column of Table 6), the length of service has 8 levels (see the first column of Table 8), the accident location has 4 levels (see the first column of Table 8), the day of the week has 7 levels (see the first column of Table 9), the time of Day has 14 levels (see the first column of Table 11), the time of the working day has 12 levels, the days of absence has 8 levels, the deviation has 9

Table 15
Accidents in the metal sector by injury and severity.

Chi-square 43,422.569 df = 42 Sig. < 0.000

Injury	Total accidents		Light		Serious		Very serious		Fatal	
	N	TAR(%)	N	LAR(%)	N	SAR(%)	N	VSAR(%)	N	FAR(%)
	275,294	100	272,854	100	2,089	100	86	100	265	100
Unknown	1,619	0.6	1,608	0.6*	11	0.5*	0	0.0*	0	0.0*
Wounds, superficial injuries	118,392	43.0	118,142	43.3	247	11.8	2	2.3	1	0.4
Crushed bones	22,632	8.2	21,685	7.9	923	44.2	21	24.4	3	1.1
Dislocations, sprains, and strains	105,137	38.2	105,065	38.5	71	3.4	1	1.2	0	0.0
Amputations	1,187	0.4	927	0.3	246	11.8	9	10.5	5	1.9
Concussions and internal injuries	11,737	4.3	11,518	4.2*	150	7.2	16	18.6	53	20.0
Burns	5,449	2.0	5,347	2.0*	96	4.6	4	4.7*	2	0.8*
Poisonings and infections	409	0.1	405	0.1*	3	0.1*	1	1.2	0	0.0*
Drowning and asphyxiation	265	0.1	255	0.1*	4	0.2*	3	3.5	3	1.1
Effects of noise. Vibration and pressure	395	0.1	394	0.1*	1	0.0*	0	0.0*	0	0.0*
Extreme Tempature Effects	310	0.1	309	0.1*	1	0.0*	0	0.0*	0	0.0*
Psychic trauma, traumatic shock	671	0.2	656	0.2*	8	0.4*	0	0.0*	7	2.6
Multiple lesions	2,406	0.9	2,077	0.8	203	9.7	19	22.1	107	40.4
Heart attacks, strokes, and other nontraumatic diseases	369	0.1	167	0.1	109	5.2	9	10.5	84	31.7
Other injuries	4316	1.6	4299	1.6*	16	0.8	1	1.2*	0	0.0

* : Corrected standardised residuals < 1.96 in absolute value.

levels, and injury has 15 levels (see Tables 12 to 15). The results of the ANOVA tests are shown in Table 16, and p values in bold correspond to significant effects. The p value for the analysis of the variance F test ($p < 0.005$, 95% confidence level) suggests that location, company staff, deviation, days of absence, time of day, injury variables, and company staff and deviation interaction are significant in severity's results. However, the degree of influence was low (days of absence: percentage of variance associated with 28.48%), which together accounted for 49.04%. Cohen's guidelines determined the effect sizes to be small. ANOVA results align with the analysis of the contingency table.

4. Conclusions

Our findings suggest that the sector in Spain has slightly improved the accident rate over the last decade, but it still accounts for a high percentage of the Spanish's industry's serious and fatal accidents, mainly in autonomous communities where it has the greatest influence on the economy.

The study variables and severity are related. Location, company staff, deviation, days of absence, time of day, and injury are significant in the severity of accidents at the 95% confidence level in Spain's metal sector.

Regarding the injury type, amputations, crushed bones, concussions and internal injuries are mainly related to severe, very severe or fatal accidents in the metal sector.

Loss of machine control, falls and slides could have higher accident severity than others in Spain's metal sector.

Most accidents occur in the workplace in the metal sector, but the percentage of very serious and fatal accidents in the usual workplace drops considerably.

Length of service-severity distribution is not uniform. The highest number of serious accidents occurs in the age ranges closest to retirement (60 years and older); therefore, it would be interesting to implement sectoral and/or company policies that attempt to reduce the serious accident rate in these age ranges, such as shorter working hours and combining administrative, control, and/or sorting and cleaning tasks.

More accidents occur in small- and medium-sized companies, but the rate of serious accidents per number of accidents is higher in large companies, which aligns with length of employment in the company. Therefore, it is necessary to provide training and information on procedures and occupational safety to newly hired workers. Additionally, companies should create training plans for recycling in risk prevention, especially when new technologies create new and emerging risks.

The 'Monday effect' and meal breaks affect the accident rate in the metal sector; thus, control actions by employers in these time slots are necessary.

4.1. Limitations

The first limitation of the study is the source of the data. Although all accidents that occurred in the metal sector between 2009 and 2019 were analysed, some accidents may not have been reported. The second limitation is that specific data on the description of work-related accidents are not available, although this study's results are of general interest for the entire metal sector in Spain. The possibility of having accident reports available for a specific group could make it possible to establish relations between these data and those obtained in this study and to create safer working conditions.

The third limitation is that accidents in which the worker did not miss any days of work are not reflected in the accident reports. The fourth limitation is that no data are available for hours worked according to the different studied variables; therefore, variable-specific incidence rates cannot be calculated.

Table 16
Severity. Analysis of Variance.

SOURCE	SS	DF	RMS	P value	Effect Size (η^2)
MAIN EFFECTS					
Location	386	3	128.6120	**<0.0001**	0.0806
CNAE	0.173634	12	0.0145	0.1456	<0.0001
Day of the Week	0.097849	6	0.0163	0.1407	<0.0001
Company Staff	0.349836	6	0.0583	**<0.0001**	0.0001
Age	0.060902	7	0.0087	0.5398	<0.0001
Time of Day	0.235808	11	0.0214	**0.0164**	<0.0001
Time of the Working Day	0.160554	13	0.0124	0.2591	<0.0001
Deviation	212	8	0.2649	**<0.0001**	0.0443
Injury	198	14	14.1620	**<0.0001**	0.0414
Length of Service	0.041043	7	0.0059	0.7747	<0.0001
Days of Absence	1362.5	7	194.6430	<**0.0001**	0.2848
INTERACTIONS					
Company Staff - Deviation	187	48	0.0390	**<0.0001**	0.0391
RESIDUAL	2792.85	275,151	0.0102		
TOTAL (CORRECTED)	4784.08	275			

4.2. Future research

Future work includes similar analyses in other countries to compare the results and determine whether some of the conclusions apply to the entire metal sector. Some variables should also be deeply analysed to provide further details and thus create suggestions to reduce the accident rate. For example, researchers should more deeply analyse the type of deviation that causes the accident, given that more than 70% of accidents are caused by voluntary body movement, involuntary body movement, and loss of machine control, or the influence of the group of injuries 'heart attacks, strokes, and other nontraumatic diseases' which account for nearly 32% of fatal accidents in the sector.

CRediT authorship contribution statement

J.L. Fuentes-Bargues: Conceptualization, Writing-original draft, Methodology, Writing-review & editing. **A. Sánchez-Lite:** Writing-original draft, Methodology, Writing-review & editing. **C. González-Gaya:** Supervision, Resources. **Victor Fco. Rosales-Prieto:** Visualization, Writing-review & editing. **G. Reniers:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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