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Descriptive analysis and a proposal for a predictive model of fatal occupational accidents in Spain

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A R T I C L E I N F O

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A B S T R A C T

Accidents at work are a problem in today's economic structures, but if they result in the loss of human lives, the economic and social cost is even higher. The development of prevention policies, both at governmental and sectoral level, has led to a progressive reduction of occupational accidents, but number of fatal accidents remain high. The aim of this study is to explore the evolution of fatal accidents at work in Spain for the period 2009–2021, analyse the relationship between the main variables, and propose a predictive model of fatal occupational accidents in Spain. Data for this study are collected from occupational accident reports via the Delt@ (Electronic declaration of injured workers) IT system. The study variables were classified into five groups: temporal, personal, business, circumstances, and consequences. Fatal accidents at work are more common in males and in older workers, especially in workers between 40 and 59 years old. Companies with less than five workers have the highest percentage of fatal accidents, and the transport subsector and that the worker is carrying out his/her usual work have a strong correlation in the fatal accidents. Results can help to the agents involved in the health and safety management to develop preventive measures, and action plans.

1. Introduction

An occupational accident is defined as an event occurring during the working time, resulting in a non-fatal injury with loss of working time or a fatal injury [1]. As the reports of the International Labour Office (ILO) indicate, every 15 s, a worker dies from a work-related accident or disease, and every 15 s, 153 workers have a work-related accident [2], which is a serious health problem worldwide [3]. The death of a person during working time is a high cost for families, employers, and society at large [4–6]. It is estimated that the inadequate practices of safety and health could involve 4 % of the global Gross Domestic Product (GDP) each year [2].

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Fatal occupational accidents are influenced by many factors, such as the technical and organizational conditions of companies, the adaptation of jobs to employees and workers' attitudes towards occupational safety and health [7], so it is important to investigate accidents to discover the causes of occupational injuries [8]. To prevent similar accidents from occurring, investigation of occupational accidents is an essential step in the design and development of appropriate preventive measures [9–12].

A distinction is made between different approaches to occupational accident research, the analysis of accidents that have occurred in individual companies to extrapolate the results to the sectors in which they operate [13,14] or the statistical analysis of historical accident data collected by governmental safety and health agencies [15–17]. This approach allows the identification of the causes of accidents and the design of preventive activities with a more general approach [18].

The analysis of historical accident data has the disadvantage of a lack of standardization worldwide, especially in developing countries, they do not have reliable information on their occupational accidents due to a lack of proper recording and notification systems [19]. In developed countries, the accident notification systems are more rigorous in their data collection, although there are differences in procedures. For example, in the European Union, the data collected in the European Statistics on Accidents at Work (ESAW) are provided by national insurance systems for accidents at work or by relevant national authorities such as labor inspectorates in the framework of a universal social security system [20]. This does not happen with fatal accidents; data have a high level of comparability between all countries because fatal accidents are usually investigated by relevant state authorities.

Changes in working practices and health and safety standards in recent years have led to a reduction in the number of occupational accidents and fatal accidents [18,21], but the number of lives lost is sufficiently high to justify further research in this area [22,23].

Work on historical accident analysis focuses mainly on specific production sectors [24–27], and the construction sector is the most studied sector [28–32]. Fatal accident investigations distinguish between those that focus on dealing with work-related mortality in a specific area, such as shipyard workers [33], fertilizer transporters [34] or military peacekeepers [35]; and those that are not focused on a specific sector, or point to two or more economic sectors with a significant rate of work-related deaths, such as [4,5,21,36–38] and especially in the construction sector such as [8,12,39,40].

There is not much research in the literature that focuses on analysing only fatal accidents at the national level: Saloniemi and Oksanen in Finland [41], Santos et al. in Portugal [42], Asady et al. in Iran [43], Hansen in Denmark and Sweden [44], Kang et al. in South Korea [45] and Gómez García et al. in Ecuador [46]. These types of studies give an overall picture of the characteristics, causes, and conditions of fatal accidents. No similar study has been carried out in Spain, which is the gap to be filled by this work.

The main aim of this research is to carry out an analysis of fatal occupational accidents in Spain over the last fifteen years and analyse the relationship between the variables associated with accidents. The results of the study provide a framework for improving safety practices, providing a valuable reference for all agents involved in health and safety at work to improve risk management, preventive measures, and action plans, and thus limit the social and economic impact of accidents. The rest of the article is structured as follows. Section 2 presents a review of the literature on fatal accidents, and Section 3 describes the methodology. Results are presented in Section 4 and the discussion with previous research is developed in Section 5. Finally, Section 65 shows the conclusions of our research.

2. Literature review

Finally, Section 6 shows the conclusions of our research model of occupational accidents. According to this model, material hazards, incidents, minor accidents, major accidents, and fatalities at work follow the same, albeit decreasing, logic [47]. Thus, one death at work is a signal of many safety and production problems in the workplace, and safety problems can be addressed to prevent that one death [48].

This model has been present among the main premises on which occupational safety management is based [7], on the basis that accidents have a common cause [49,50]. This model has been challenged over the years, but there are many studies that justify a different causality for fatal and non-fatal accidents [41,51], which justifies a separate analysis of severe and fatal accidents [52].

The development of more effective preventive activities involves the study of the variables that influence the sequence of accidents. Research about occupational accidents has identified personal variables such as age, experience, and skills [16,53]; organizational and socio-economic variables [54,55]; 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 [29,56].

Among the most analyzed personal variables are sex and age. Regarding the sex of the worker, many studies conclude that it is not a predictor variable for occupational accidents [57,58], although it seems to be common for a greater number of accidents to occur in male workers, normally explained by the higher employment rate of these and because they tend to carry out the jobs with greater exposure to risk [3,59]. About age, there are studies with conclusions showing the influence of age [57] and others that do not signify its non-influence [60], although the indicated references analyzed a single business sector and both fatal and non-fatal accidents. Also, some studies claim higher mortality in older workers [61,62], and others claim higher mortality in younger workers [59,63]. In nationwide research on fatal accidents, Santos et al. [42], in a study for Portugal, showed that the probability of suffering a fatal accident is related to the increasing age of workers. Hansen [44] reached the same conclusion for Denmark and Sweden and Gómez-García et al. [46] in their study in Ecuador concluded that accidents are more frequent in older but less experienced workers.

Regarding the influence of time variables on the fatal accident rate, distribution by month has been analyzed for Xu and Xu [40] in the construction sector of China, where the largest number of deaths occurred in August, October, and July. Among the possible explanations, the authors determined possible causes natural meteorological conditions and disasters such as high temperatures, thunder and lightning, rainstorms, and typhoons frequently occur during these months. The possible influence of the day of the week has been extensively studied in the literature, both with fatal and non-fatal accidents, although with different conclusions. For non-fatal accidents, the "Monday effect" [64], i.e., the high number of occupational accidents occurred on Mondays, because of some injuries occurred during the weekend are reported on Monday because insurance companies compensate more for work-related injuries than for those that occur during leisure activities, can be the justification for other similar research findings [16,29]. In studies focusing only on fatal accidents, Szóstak [65] noted in his study in Poland in the construction sector that fatal accidents most frequently occurred on Wednesdays and Thursdays. On the other hand, Gómez-García et al. [46] in their study on fatal accidents in Ecuador indicated that the worst days were Tuesdays and Fridays. Furthermore, they stated as a possible explanation for the accident rate on Fridays; it could be the pressure to finish the work before the weekend and accumulated physical-mental fatigue. In contrast, Xu and Xu [40] determined that Monday was the day with the most fatal accidents in their study in Chinese construction.

Another time variable studied is the time of day, Zermane et al. [23], in comparing fatal accidents in the construction sector between the USA and Malaysia, identified that 42 % of accidents occurred between 8:00 and 12:00. Although not only for fatal accidents, Szóstak [65] in his study in Poland, establishes a correlation between the time of day and the time of the working day, indicating high correlations between 7:00–7:59 and the first hour of the working day and between 14:00–14:59 coinciding with the last hour of the working day.

With regard to organizational variables such as the economic sector, Santos et al. [42], in a study conducted in Portugal on a sample of accidents between 2013 and 2015, demonstrated that there is no justification that workers have a higher probability of suffering an accident because they belong or not to sectors traditionally with a higher accident rate, as is the case of construction, but the fact is that it is the construction sector is by far the most studied sector in terms of fatal and non-fatal accidents [23,40,65]. Darda'u Rafindadi et al. [8], in their study of 302 fatal accidents between 2009 and 2019, found that fatal construction accidents are caused by management factors, hazardous site conditions, and workers' risky behaviors and that the level of safety in the construction industry is strongly dependent on these three crucial aspects. Other authors also point out that in some regions, the working day in the construction sector is extended to Saturdays, which means greater exposure to risk factors [46] and other research strongly emphasizes the high incidence of subcontracting on mortality in the construction sector [66,67].

Fatalities have also been studied in other sectors, such as the manufacturing sector [37], in the shipyard [33], or in farming and forestry [21]. Nenonen [37] concluded the work process with more fatal accidents were installation and preparation, as well as maintenance and repairs. In the shipyard in Turkey, Barlas and Iczi [33] concluded that fire/explosion and struck by/struck against objects and caught in between were the main fatality reason for the ship and shipyard, respectively. Thelin [21] analyzed fatal accidents in Swedish farming and forestry between 1988 and 1997 and identified that the most common accident type in agriculture was those involving tractors and machinery, while in forestry, by far the most fatal accidents were related to chainsaw work (77.9 %).

Work experience, especially on the job, is one of the organizational variables studied by some authors. Szóstak [65] found in his study of occupational accidents in the construction sector in Poland between 2008 and 2017 that 14 people died on the first day of work, 46 during the first week of work, and 75 during the first month of work. This data leads to the conclusion that more experience in the workplace reduces the number of accidents, a conclusion endorsed in other studies such as in the construction sector [43], in the manufacturing sector [41] or in shipyard jobs [33].

The deviation that generates the fatal accident, the injury that causes death, and the part of the body affected depends on the sector where the worker works [15]. Santos et al. [42], in their research in Portugal, determined the exposure of workers to deviations by overflow, overturn, leak, flow, vaporization, or emission increased the probability of becoming victims of fatal accidents. In contrast, for the manufacturing sector, Nenonen [37] determined that breakage, bursting, splitting, fall, or collapse of the material agent was the most common deviation. Regarding injuries, Thelin [21] indicated that suffocation/crushing followed by cranial injuries/brain damage were the main in the farming and forestry sectors in Sweden. Santos et al. [42] determined musculoskeletal disorders, wounds and fractures, and amputation were the most common type of injuries leading to occupational fatalities in Portugal. In Brescia County (Italy), Perotti et al. [3] concluded by analyzing the autopsy results of the Institute of Forensic Medicine most fatal injuries were caused by mechanical trauma (78 %), such as falls, machinery-related events, blunt force, sharp force, or explosions.

3. Material and methods

3.1. Scope and accident data

The study focuses on the analysis of fatal accidents at work in Spain between 2009 and 2021 to know the characteristics and related variables associated with accidents. The time frame studied coincides with other studies on occupational accidents carried out in Spain and with the latest consolidated data published.

Directive 89/391/EEC of the Council of the European Communities [68] made it compulsory to have a common framework to process all data related to occupational accidents in EU member states. In Spain, the information provided in occupational accident reports is structured in accordance with Act TAS/2926, November 21, 2002 [69] and collected via the Delt@ (Electronic declaration of injured workers) IT system.

In the accident reports, the severity of the accidents is classified as light, serious, very serious and fatal. Accidents were considered fatal when the worker dies and as such is reflected by the medical services of the mutual insurance companies. Some examples of fatal accidents can be caused by construction workers falling from different levels, accidents of transport service drivers and/or trapping and cutting on machines in manufacturing industries.

In this analysis, the data used correspond to fatal accidents during the working day, including accidents "in itinere" (accidents to and from home to the workplace) in Spain between 2009 and 2021.

3.2. Analysis design

Fig. 1 shows the steps proposed in this study, the analyses conducted, and the objectives of each step.

The data analysis has been divided into two steps. The first step presents a descriptive analysis of the fatal accidents according to different variables, such as the period of the study, the Spanish regional state where the accident occurred, and the National Classification of all Economic Activities (CNAE) [70] , which is similar to the coding used by the European classification of economic activities (NACE).

Descriptive statistics were calculated to summarize the basic features of the data, and a correlation analysis using Spearman's coefficient was applied to detect dependence, and strength, between the variables. With a significance level of <0.05, the dependence between the variables analyzed can be shown with a 95 % confidence level. Subsequently, the variables with the greatest dependence are compared by means of the frequency of accidents and the percentage of accidents with respect to the overall number, so that aspects can be identified that allow conclusions to be drawn for the design of specific preventive actions.

The data used in this research refer to the number of accidents that occurred, not to the incidence rates, as data on the number of workers according to each of the variables studied are not available.

The second consists of the analysis of the influence of a selected variables on fatal accidents. These variables are collected in the notification reports of work accidents and have been used in previous research conducted in other industrial sectors, such as in the construction sector [5,28,29], in the metal sector [27], in the Andalusian (Spain) public universities [25], and in the mining sector [26].

First in step two, a two-stage cluster analysis [71] was used to identify subgroups of fatal accidents. This cluster analysis can deal with both ordinal and nominal variables. Two-step cluster analysis automatically determines the optimal number of clusters. In this case, the BIC (Schwarz Bayesian Information Criterion) method was used to determine the optimal number of clusters [72,73]. Cluster quality was evaluated following the measure of cohesion and separation of Rdusseeun & Kaufman studies [74]. Two cluster analyses were developed, one based on all fatal accidents in the database ($N = 8974$) and the other one considering only the year with the number of fatal accidents closest to the mean of fatal accidents in the database ($N = 693$). The variables included in both cluster analyses were selected considering the results achieved in the first step of the study.

Secondly in step 2, a logistic regression analysis [75–77] was used to develop a predictive model of fatal occupational accidents. Logistic regression analysis has been successfully applied in several studies to develop a predictive model for fatal accidents [42,43,59,78–81]. This logistic regression model allows us to estimate the probability of a fatal occupational accident (dependent variable) from a given data set for the independent variables. Independent variables of the predictive model were identified using the results of the accident rate study (step 1) and cluster analysis. In generating the model, statistically predictor variables were selected by the forward stepwise method [82,83]. The Wald test [84] was used to determine the significance of each variable in the model. The goodness of fit of the model was evaluated using Nagelkerke R Square coefficient [85]. Hosmer and Lemeshow test [86] assessed the fit of the model against the data, and the model predictions versus actual observations were compared using the classification table.

All statistical analyses were performed using the software IBM SPSS® Statistics (Version 29.0) [87].

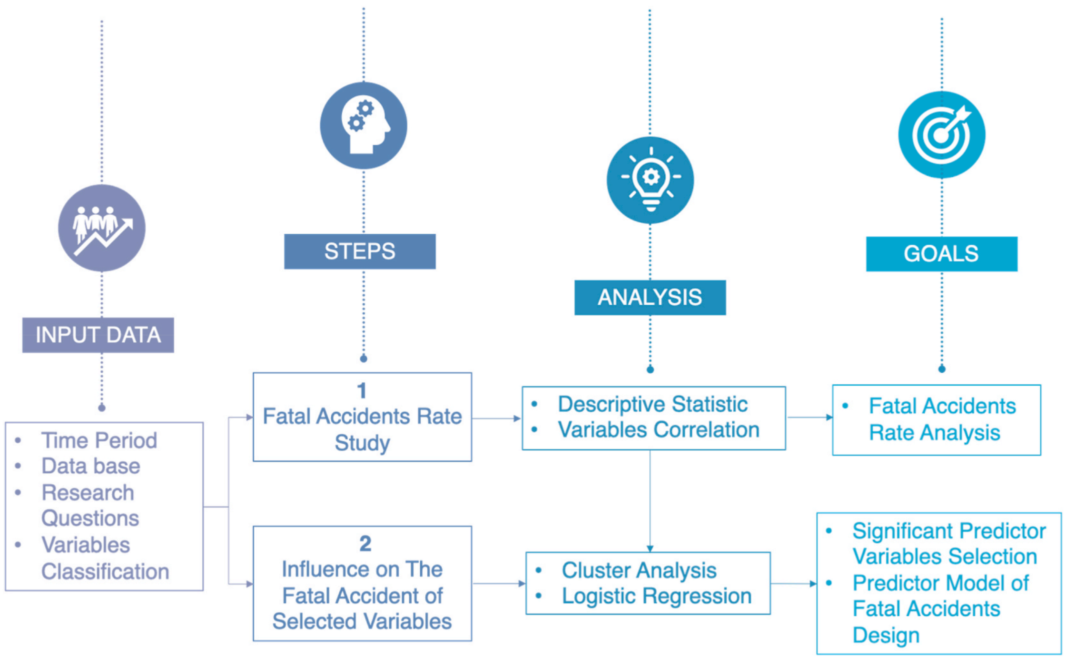

Fig. 1. Methodological framework of data analysis: Input data, stages, analysis approach, and goals. Source: Own elaboration.

Table 1
Classification and description of variables and categories of the research.

Id	Variable group	Id	Variable	Variable Description	Category	
					Number categories	Values
T	Temporal	T1	Year	Year of the accident	13	2009 to 2021
		T2	Month of the year	Month of the accident	12	January to December
		T3	Day of the week	Day of the week of the accident	7	Monday to Sunday
		T4	Time of day	Time of day of the accident.	14	8:00–8:59; 9:00–9:59; 10:00–10:59; 11:00–11:59; 12:00–12:59; 13:00–13:59; 14:00–14:59; 15:00–15:59; 16:00–16:59; 17:00–17:59; 18:00–18:59; 19:00–19:59; 20:00–20:59; Rest of hours
		T5	Time of the working day	Time of the working day when the accident occurs.	12	0 to 10; >10
P	Personal	P1	Gender	Worker's sex	2	Male or female
		P2	Age	Worker's age (years old)	8	16-19; 20–24; 25–29; 30–39; 40–49; 50–59; 60–69; >70
B	Business	B1	CNAE	Spanish National Classification of all Economic Activities (CNAE), grouped under headings	21	Agriculture, livestock, forestry, and fisheries; Extractive industries; Manufacturing Industry; Electricity, gas, steam, and air-conditioning supply; Water supply, sewerage, waste management, and remediation activities; Construction; Wholesale and retail trade, repair of motor vehicles, and motorbikes; Transport and warehousing; Hotels and restaurants; Information and communications; Financial and insurance activities; Real estate activities; Professional, scientific and technical activities; Administrative and support service activities; Public administration and defense; compulsory social security; Education; Health and social work activities; Arts, entertainment, and recreation; Other service activities; Activities of households as employers of domestic servants; Activities of territorial organizations and bodies
		B2	Company staff	Company size, in terms of the number of workers.	7	≤5; 6–10; 11–25; 26–50; 51–100; 200–250; >250
		B3	Length of Service	Length of service of the worker, in terms of months and/or years of experience	8	<1 month; 1–3 months; 4–12 months; 1–2 years; 3–4 years; 5–10 years; 11–30 years; >30 years
		B4	Health and Safety preventive organization	Type of preventive organization regarding health and safety at work	6	Entrepreneurial assumption; Own prevention service; External prevention service; Designated workers; Joint prevention service; No preventive organization
		B5	Employment status	Worker's type of employment status.	6	Full-time permanent contracts; Part-time permanent contracts; Indefinite-term contracts, permanent discontinuous; Full-time temporary contracts; Part-time temporary contracts; Other employment relationships
		B6	Risk assessment	Risk assessment available at the company	2	Yes or no
C	Circumstances	C1	Accident location	Location of accident	4	Usual workplace; Moving between work areas; Going to or coming from worksite; Different workplace
		C2	Usual work	The accident occurs when the worker is carrying out his/her usual work.	2	Yes or no
		C3	Physical activity	Describes the specific activity that the injured worker was carrying out immediately before the accident occurred.	9	No information; Machine operations; Work with hand tools Transport or loading equipment; Handling objects; Manual transport; Movement; Being present; Other activity
		C4	Deviation	Describes the abnormal occurrence that has adversely interfered with the normal process of work performance and has led to the occurrence or origin of the accident.	10	No information; Electricity, explosion, fire; Dump, scape; Fall, slide; Loss of machine control; Falls involving people; Voluntary body movement; Involuntary body movement; Shock or jolting action; Oters

(*continued on next page*)

Table 1 (*continued*)

Id	Variable group	Id	Variable	Variable Description	Category	
					Number categories	Values
CQ	Consequences	CQ1	Injury	Description of the physical consequences of the accident for the victim. If there are several injuries, the most serious injury is chosen.	15	No information; Wounds, superficial injuries; Crushed bones; Dislocations, sprains, and strains; Amputations; Concussions and internal injuries; Burns; Poisonings and infections; Drowning and asphyxiation; Effects of noise. Vibration and pressure; Extreme temperature Effects; Psychic trauma, traumatic shock; Multiple lesions; Heart attacks, strokes, and other nontraumatic diseases; Other injuries
		CQ2	Body part injured	Part of the body affected by the injury	9	Not specified; Head; Neck; Back, including spine and vertebrae; Trunk and organs; Upper limbs; Lower limbs; Whole body and multiple parts; Other parts of the body not mentioned

3.3. Study variables and research questions

The study variables were selected from the official occupational accident forms according to similar studies [25,28,29]. According to the methodology applied by Refs. [25,28] the variables were grouped to answer questions such as: When does the accident occur? Who is the most at risk? How do the characteristics of the company and labor contracts affect accidents? What circumstances surround the accident? What are the consequences of the accident? These five questions provided the structure of the research, classifying the variables into five groups: temporal, personal, business, circumstances, and consequences. In Table 1, the groups and the variables are described. In the last two columns, the number and the description of the categories are defined.

4. Results

4.1. Descriptive analysis

A total of 8974 fatal accidents occurred in Spain between 2009 and 2021, 8242 in men (91.8 %) and 732 in women (8.2 %). This percentage varies greatly with the male and female employment rate in Spain during the study period, where the percentage of employed male and female staff ranged between 54 and 56/46-44 % according to the Labour Force Survey elaborated by the Spanish National Statistics Institute [88].

The evolution of fatal accidents in the study period is shown in Fig. 2. An initial decrease in the number of fatalities can be seen coinciding with the decrease in activity because of the economic crisis [89] and the actions taken by the Spanish government to improve occupational risk prevention [90,91]. After the recovery of economic activity, the number of occupational fatalities increased and remained stable at more than 700 deaths per year.

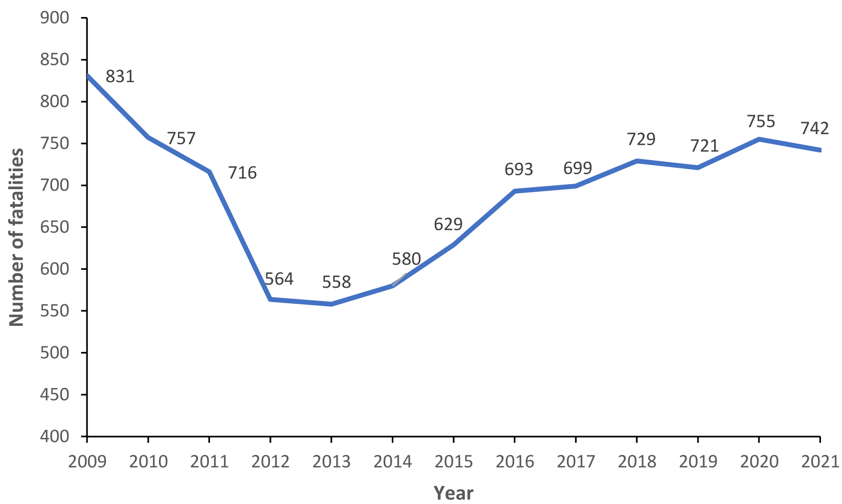

Fig. 2. Trend of fatal accidents in Spain (2009–2021). Source: Own elaboration based on data from Spanish Delt@ IT system.

If the data are analyzed from the point of view of the nationality of the workers, 7828 (87.2 %) were Spanish, following a similar trend to the evolution curve of the total number of fatal accidents. About other nationalities, Romania (270 deaths and 3 %), Morocco (167 deaths and 1.9 %), Portugal (97 deaths and 1.1 %), Bulgaria (95 deaths and 1.1 %), and Ecuador (64 deaths and 0.7 %) are the nationalities of the workers with the most accidents, accounting together with the Spanish nationality for 95 % of the fatal accidents in the study period.

Another important aspect is the distribution of fatal accidents according to geographical distribution [92]. Spain is composed of 17 autonomous communities and two autonomous cities (Ceuta and Melilla). Table 2 shows the fatal accidents (number and percentage) by autonomous communities. The autonomous communities are divided into provinces, reaching a total of 50 provinces. In Fig. 3 can see the percentage of fatal accidents by province.

There are no public data on economic activity by subcodes of the National Classification of Economic Activities (CNAE) or employment data by subcodes of the CNAE, so the assumption is made that greater general economic activity means greater hiring of personnel and, therefore, greater exposure to risks at work. The major exposure to risks implies a higher probability that an occupational accident may occur. In Spain, the autonomous communities with the best economic rates are Catalonia, Andalusia, Valencia, Madrid, the Basque Country, and Galicia [93]. In Table 2 we can observe this situation except for the Basque Country, which has a lower mortality rate than other communities with a lower turnover, such as Castille Leon or with values close to those of Castille La Mancha.

Fig. 3 shows the fatal accidents (%) at work by province. Madrid (10.8 %), Barcelona (9.9 %), and Valencia (5.4 %) account for the highest number of fatal accidents during the study period. In a second group are the provinces of A Coruña, Seville, Alicante, Murcia, and Pontevedra. The province of Alava stands out for its low accident rate with respect to the level of business [92], and the provinces of Ávila and Soria (with 40 fatalities each) and the cities of Ceuta and Melilla (10 and 7 fatalities respectively) stand out as provinces with the lowest accident rates.

The evolution over time of fatal accidents according to the CNAE is shown in Table 3.

Table 4 provides a more detailed analysis of the CNAE (with the three-digit classification), identifying the sub-categories with more than 150 deaths during the study period, to identify some more specific sub-categories that might lose their importance if the more general classification is analyzed. In addition to the sub-categories included in the construction sector (412, 432, 439, and 461), sub-categories 11 and 12, related to agriculture, should be highlighted. Between them, they account for 422 accidents in the study period (4.7 %), a very significant percentage for the total number of people employed and the level of activity (4.2 % of the labour force and 2.6 % of the Spanish Gross Domestic Product for the year 2021) [89,94].

The sub-category "Road haulage and removal services" presents the highest accident rate in the period. This leads us to reflect, and more especially for this sub-category, on the accident location: in itinere (going to or coming from worksite at home), moving between work areas, in the usual workplace or in a different workplace, as well as to see how many traffic accidents are. In the historical series, the distribution of where accidents occur does not show great variations, except for the year 2020, where there is a considerable decrease in both accidents in itinere and traffic accidents.

Table 5 shows that 20.6 % of accidents at work occur in itinere and 28.5 % in journeys between workplaces or in the performance of the activity itself, such as "Road haulage and removal services." In this subcategory, road accidents account for 55.5 % of the total (588/1060) and 66 % of movement between different workplaces (527/799), so it would be necessary to promote training and information on the risks involved in road transport through more general campaigns such as those developed for the population by the Directorate General of Traffic or similar agencies.

Table 2
Fatal accidents by autonomous communities (2009–2021).

Autonomous communities	Fatal Accidents	
	N	%
Andalusia	1415	15.8
Aragon	369	4.1
Asturias	241	2.7
Baleares	123	1.4
Canarias	293	3.3
Cantabria	130	1.4
Catalonia	1358	15.1
Castille Leon	642	7.2
Castille La Mancha	462	5.1
Valencian Community	886	9.9
Extremadura	220	2.5
Galicia	818	9.1
La Rioja	79	0.9
Madrid	965	10.8
Murcia	328	3.7
Navarre	160	1.8
Basque Country	468	5.2
Ceuta	10	0.1
Melilla	7	0.1

N number of fatal accidents; % percentage of the total fatal accidents.

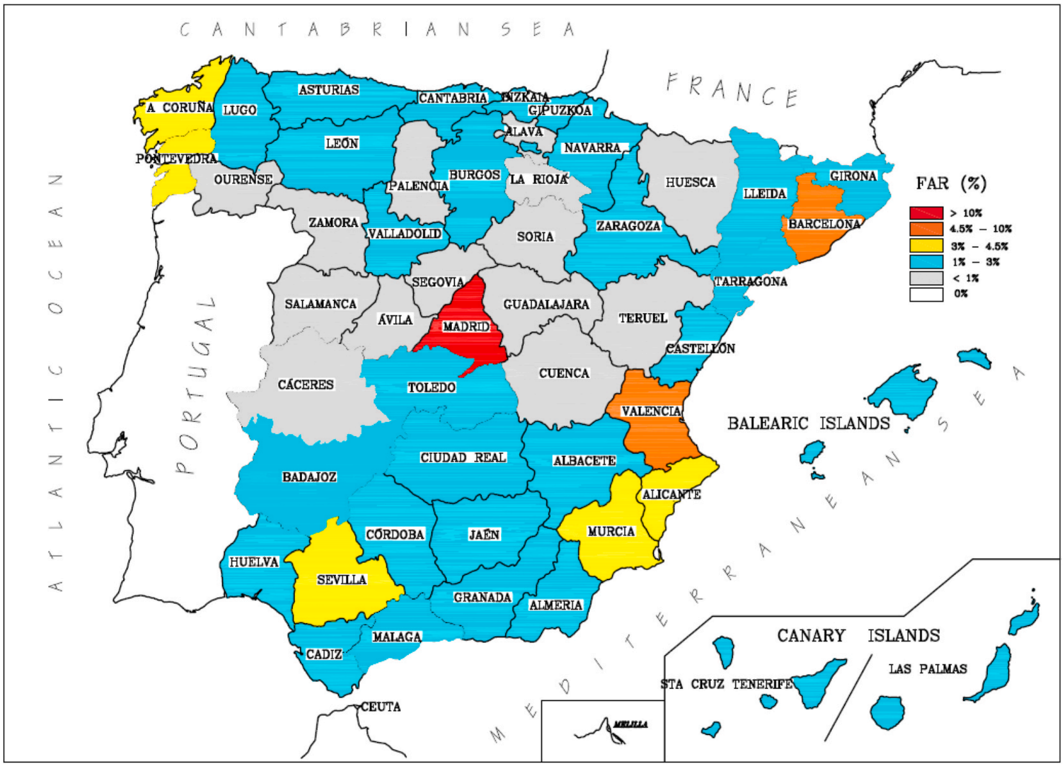

Fig. 3. Fatal accidents (percentage) by provinces (2009–2021). Source: Own elaboration based on data from Spanish Delt@ IT system.

4.2. *Relationship between variables associated with the fatalities*

Table 6 shows the results of the test of independence (Spearman's correlation coefficient) carried out between the main variables considered in this research study. Most of the relationships between the variables were statistically significant at 95 % and 99 %, but the strength of the relationships was very weak. We found two strong correlations, on the one hand, Length of service (B3) and Employment status (B5) and, on the other hand, Deviation (C4) and Injury (CQ1). Also, medium strength correlation between three pairs of variables has been identified: Deviation (C4) and Body part injured (CQ2); Accident location (C1) and Usual work (C2), and Time of the working day (T5) and Usual work (C2). In the following subsections, the main results of the relationships are described.

4.2.1. *- Temporal variables*

Table 7 shows a distribution of fatal accidents according to the time variables: month, day of the week, daytime, and time of the working day. Firstly, there is a similar distribution of fatal accidents in all months of the year, except for August and December, which coincides with the reduction in work activity because of the summer holidays and the Christmas holidays.

4.2.2. *- Personal variables*

Table 8 shows the distribution of accidents by personal variables. Age fatality is not uniform. The age ranges with the highest accident rates are between 50 and 59 (35.0 %) and between 40 and 49 (29.7 %). Regarding the distribution between men and women, the highest accident rate is found among women between 40 and 49 years (2.4 % of the global), while among men, it is found in the 50–59 years group (32.8 % of the global).

4.2.3. *- Business variables*

In the analysis of the business variables, we first studied the distribution of fatal accidents with respect to the categories of CNAE with the fatal accident rate (Table 9). The seven categories of Table 9 account for 68.1 % of fatal accidents. Companies with less than five workers have the highest percentage of fatal accidents (21.0 %), the most common due to the characteristics of the Spanish economy.

In the "Agriculture, livestock, forestry and fisheries" category, this value rises to 49.4 % for companies with less than five workers, and in the "Construction", the "Wholesale and retail trade" and "Transport and warehousing" categories of CNAE the percentage reach values of over 40 % for companies with up to 10 workers (43.6 %, 42.1 % and 41.6 % respectively). On the other hand, in the "Manufacturing Industry" category, the values of mortality for companies with less than five employees are also very high, although the number of accidents remains stable in all company sizes.

Table 3
Trend of the number of fatal accidents by CNAE (2009–2019).

CNAE	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	TOTAL
Agriculture, livestock, forestry, and fisheries	71	60	72	65	56	88	71	86	72	87	56	105	63	952
Extractive Industries	13	9	10	9	12	5	8	4	4	8	1	5	7	95
Manufacturing Industry	118	118	115	85	82	84	121	102	92	104	109	132	107	1369
Electricity, gas, steam, and air-conditioning supply	5	3	2	3	2	2	3	0	1	2	1	1	1	26
Water supply, sanitation, waste management, and decontamination activities	12	14	6	13	8	8	13	9	21	14	12	12	20	162
Construction	208	175	152	95	86	86	94	90	107	121	167	134	141	1656
Wholesale and retail trade; repair of motor vehicles and motorbikes	104	82	75	59	61	54	63	65	77	71	73	55	83	922
Transport and warehousing	116	100	101	83	82	101	99	142	118	120	129	115	134	1440
Hotels and restaurants	26	19	17	22	18	30	31	31	42	27	26	29	25	343
Information and communications	6	9	6	4	6	3	7	12	8	6	8	4	4	83
Financial and insurance activities	4	14	7	6	6	3	5	9	7	6	2	2	3	74
Real estate activities	0	0	1	2	1	0	1	1	0	3	1	3	1	14
Professional, scientific, and technical activities	13	24	16	12	10	10	11	17	13	11	14	9	14	174
Administrative and support service activities	47	45	53	37	40	40	46	60	59	60	53	50	50	640
Public administration and defense; compulsory social security	38	43	37	35	39	25	25	30	37	39	23	30	31	432
Education	7	10	13	5	7	4	7	5	7	9	6	7	5	92
Health and social work activities	22	14	18	14	26	24	13	15	19	21	24	42	36	288
Arts, entertainment, and recreation	10	4	8	6	9	3	3	6	7	10	10	7	8	91
Other service activities	9	8	6	6	5	6	5	5	6	6	3	8	5	78
Activities of households as employers of domestic servants	2	6	1	3	2	4	3	4	1	4	3	5	4	42
Activities of territorial organizations and bodies	0	0	0	0	0	0	0	0	1	0	0	0	0	1

Table 4
Fatal accidents by CNAE (three-digit classification).

CNAE	Description	N
494	Road haulage and removal services	1060
412	Building Construction	622
432	Electrical, plumbing, and other installations on construction sites	377
841	Public administration and economic and social policy administration	347
11	Agriculture. Non-perennial crops	216
439	Other specialized construction activities	215
12	Agriculture. Perennial crops	206
31	Fishing	168
463	Wholesale trade of food, beverages, and tobacco.	164
461	Demolition and site preparation	161
812	Cleaning activities	159

N number of fatal accidents.

Table 5
Accident location and traffic accidents for global CNAE and sub-category "Road haulage and removal services".

Description	In itinere		Usual place of work		On movement		Other workplaces		Total	
	N	%	N	%	N	%	N	%	N	%
Global CNAE	1848	20.6	3642	40.6	2556	28.5	928	10.3	8974	100
Traffic Accidents at work at global CNAE	1626	57.7	11	0.4	1171	41.6	10	0.4	2818	100
Sub-category 494	69	6.5	114	10.8	799	75.4	78	7.4	1060	100
Traffic Accidents at work in sub-category 494	61	10.4	–	–	527	89.6	–	–	588	100

N number of fatal accidents; % percentage of the total fatal accidents.

In Table 10, the distribution of fatal accidents by employment status and length of service is presented. Firstly, we must indicate the Spanish labour regulation defines the possibility of the contracts being, on the one hand, full-time or part-time, and on the other hand they can be permanent or temporary. Also, there is another type, the "Indefinite-term contracts, permanent discontinuous", which is defined as a single indefinite-term contract but with successive calls, a contract whose execution is interrupted at the end of each activity period and then the worker does not work and does not receive any salary.

Of the 2000 overall deaths of workers with less than three months experience, 1566 correspond to the "Full-time temporary contracts" status, which represents 78.3 % of this type of worker (18.3 % of the total, i.e., 2 out of every 11 deaths correspond to this profile).

If the analysis of this kind of accident is performed with respect to personal characteristics (age and gender) (Table 11), it can be observed that 56.7 % of the accidents occur in men between 40 and 59 years of age, so it must be one of the segments for the design re-training formation actions.

Another important business variable to be related is the existence or not of a risk assessment in the company (or for the workplace where the accident occurred). 32.8 % of the total fatal accidents had not a risk assessment performed. This fact is striking because the European directive on occupational risk prevention [68] was transposed into Spanish law in 1995 [95], and risk assessment is one of the first steps in occupational risk prevention.

In Table 12, the number and percentage of fatal accidents are presented by the highest accident rates in CNAE categories. In all sectors, the percentage without a risk assessment in fatal accidents is higher than 50 %, reaching values of 74.5 % for the "Administrative and support service activities" category and 71.6 % for the "Construction" category.

4.2.4. - Circumstances variables

In Table 13 distribution of fatal accidents by accident location and if they were carrying out their usual work are presented. 40.6 % of the accidents occurred at the usual workplace, and of these, 94.9 % of the workers were carrying out their usual work. For accidents at "Movement between workplaces" (20.6 % of the total) and for accidents at "Different workplace" (10.3 % of the total), 94 % and 92.6 %, respectively, of the workers were carrying out their usual work.

Table 14 shows the relationship between the physical activity that the worker was doing just before the accident and the deviation that caused the accident. The physical activity that generated the highest number of fatal accidents was "Transport or loading equipment", with 3344 accidents (37.3 %), followed by "Movement" with 2714 accidents (30.2 %).

To conclude the point corresponding to circumstances variables, the variable "Deviation" is related to one of the variables corresponding to the group Consequences, such as the "Injuries" produced that caused the death of the workers (Table 15).

The great majority of fatal accidents were coded as "Multiple lesions" (44.5 %) and "Heart attacks, strokes, and other nontraumatic diseases" (35.3 %). Multiple lesions correspond to cases where the victim suffers two or more types of injury of similar severity, which may explain how several injuries after the accident can lead to death. The group "Heart attacks, strokes, and other nontraumatic diseases" corresponds to strictly natural causes caused by a given state of health, such as infarction, stroke, ictus, fainting or sudden low blood pressure, retinal detachment, etc.

Table 6
Diagram of correlation for the study variables considered (Spearman correlation coefficient).

Variable	T1	T2	T3	T4	T5	P1	P2	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	CQ1	CQ2
T1		,007	-,019	-,031**	-,007	,003	,152**	,014	-,025[a]	-,028**	,034**	,046**	-,009	-,027**	,049**	,084**	,008	,008	-,031**
T2			,019	,016	,002	-,011	-,002	,000	-,002	-,031**	,022[a]	,016	-,002	,001	-,003	-,027**	-,013	-,010	,012
T3				,076**	-,024[a]	,023[a]	-,024[a]	,050**	,029**	-,023[a]	-,013	,022[a]	-,007	,010	-,038**	,012	,002	-,001	,011
T4					,216**	,000	-,058**	,026[a]	,065**	-,047**	-,005	,022[a]	-,015	,108**	-,139**	-,041**	-,059**	-,042**	,080**
T5						-,127**	,116**	-,103**	-,077**	,041**	,030**	-,042**	,075**	-,243**	,457**	,065**	,055**	,033**	-,120**
P1							-,069**	,189**	,115**	-,005	-,071**	,045**	-,041**	,037**	-,157**	,043**	,001	,003	,021[a]
P2								,040**	,003	,318**	-,035**	-,199**	,003	-,201**	,208**	,190**	,306**	,285**	-,221**
B1									,220**	,061**	-,137**	-,039**	-,043**	,060**	-,092**	,117**	,115**	,139**	-,005
B2										,121**	-,207**	-,101**	,114**	-,028**	-,100**	,082**	,095**	,121**	-,039**
B3											-,073**	-,687**	,011	-,110**	,057**	,094**	,120**	,117**	-,102**
B4												,056**	,018	,025[a]	,035**	-,068**	-,064**	-,054**	,027**
B5													-,031**	,054**	-,027[a]	-,077**	-,080**	-,084**	,071**
B6														-,099**	,167**	,029**	,035**	,048**	-,066**
C1															-,470**	-,208**	-,274**	-,234**	,277**
C2																,174**	,203**	,165**	-,244**
C3																	,374**	,315**	-,262**
C4																		,761**	-,513**
CQ1																			-,298**
CQ2																			

[a] p-value <0.05; **p-value <0.01.

Table 7
Distribution of fatal accidents by temporal variables.

Month	Fatal Accidents		Day of the week	Fatal Accidents		Day time	Fatal Accidents		Time of the working day	Fatal Accidents	
	N	%		N	%		N	%		N	%
	8974	100.0		8974	100.0		8974	100.0		8974	100.0
January	756	8.4	Monday	1704	19.0	8:00 to 8:59	651	7.3	0	1067	11.9
February	763	8.5	Tuesday	1581	17.6	9:00 to 9:59	600	6.7	1	1206	13.4
March	751	8.4	Wednesday	1564	17.4	10:00 to 10:59	648	7.2	2	1043	11.6
April	661	7.4	Thursday	1580	17.6	11:00 to 11:59	631	7.0	3	885	9.9
May	745	8.3	Friday	1495	16.7	12:00 to 12:59	663	7.4	4	857	9.5
June	745	8.3	Saturday	688	7.7	13:00 to 13:59	569	6.3	5	787	8.8
July	878	9.8	Sunday	362	4.0	14:00 to 14:59	515	5.7	6	858	9.6
August	673	7.5				15:00 to 15:59	544	6.1	7	693	7.7
September	791	8.8				16:00 to 16:59	545	6.1	8	552	6.2
October	817	9.1				17:00 to 17:59	514	5.7	9	75	0.8
November	736	8.2				18:00 to 18:59	430	4.8	10	39	0.4
December	658	7.3				19:00 to 19:59	328	3.7	>10	148	1.6
						20:00 to 20:59	227	2.5	No data	764	8.5
						Rest of hours	2109	23.5			

N number of fatal accidents; % percentage of the total fatal accidents.

Table 8
Distribution of fatal accidents by temporal variables.

Age (years)	Gender					
	Males		Females		Total	
	N	%	N	%	N	%
<16	1	0	0	0	1	0.0
16–19	30	0.3	6	0.1	36	0.4
20–24	222	2.5	29	0.3	251	2.8
25–29	416	4.6	67	0.7	483	5.4
30–39	1355	15.1	157	1.7	1512	16.8
40–49	2453	27.3	216	2.4	2669	29.7
50–59	2944	32.8	195	2.2	3139	35.0
60–69	814	9.1	62	0.7	875	9.8
>70	8	0.1	0	0	8	0.1
Total	8242	91.8	732	8.2	8974	100.0

N number of fatal accidents; % percentage of the total fatal accidents.

4.2.5. - Consequences variables

According to Table 16, the main “Body part injured” correspond to “Whole body and multiple parts” (49.0 %) and “Trunk and organs” (35.7 %), followed by “Head” injuries (13.9 %).

Of all injuries under the "Heart attacks, strokes, and other nontraumatic diseases” category, 2786 occurred on the body part "Trunk and organs".

4.3. Cluster analyses and prediction model

In classifying the fatal accidents into homogeneous groups with similar profiles, a cluster analysis was performed by means of Two-step cluster analysis [71]. Considering the results of the correlation analysis of the variables, the variables that are correlated were not considered, and a cluster analysis was conducted using the following variables: Accident Location (C1), Usual Work (C2), Time of the Working Day (T5), Deviation (C4), and CNAE (B1), Gender (P1), Age (P2), Risk Evaluation (B6), Employment Status (B5) and Length of service (B3). The total number of fatal accidents in the reference period (2009–2021) was 8974. The Deviation variable (C4) includes several samples in which there is no information on the type of incident causing the fatal accident (samples in category 9). For this reason, these samples were not considered in the cluster analysis.

Through the clustering analysis, the samples of fatal accidents were classified into two clusters. The optimal cluster number was automatically selected by the Two-step cluster algorithm. Fig. 4 shows the pattern of the clusters and the variables included in the cluster analysis, ranked in order of overall importance for grouping within each cluster. A darker colour in the cell indicates that the variable is more important within the cluster. Both clusters show as the major predictor variables the Accident Location (C1), Usual Work (C2), Time of the Working Day (T5), Deviation (C4), and CNAE (B1). Cluster 1 contains 20.2 % of the samples and mainly corresponds to the samples in which the Accident Location (C1) is “going to or coming from worksite”, Usual Work (C2) is “no”, Time of the Working Way (T5) is “before the first hour of work”, Deviation (C4) is “loss of machine control”, Gender (P1) is "female", Age (P2) is "from 16 to 29 years old", and Risk assessment (B6) is “yes”. This group could be identified as fatal accidents in “itinere” during

Table 9
Distribution of fatal accidents by company staff and the CNAE with the highest fatal accident rate.

CNAE		Company staff																
		≤5		6–10		11–25		26–50		51–100		200–250		>250		Total		
Id	Description	N	% (Id)	N	% (Id)	N	% (Id)	N	% (Id)	N	% (Id)	N	% (Id)	N	% (Id)	N	%(Id)	% (FTA)
A	Agriculture, livestock, forestry, and fisheries	470	49.4	117	12.3	158	16.6	64	6.7	53	5.6	41	4.3	49	5.1	952	100.0	10.6
C	Manufacturing Industry	177	12.9	131	9.6	255	18.6	220	16.1	189	13.8	203	14.8	194	14.2	1369	100.0	15.3
F	Construction	479	28.9	243	14.7	357	21.6	267	16.1	152	9.2	104	6.2	54	3.3	1656	100.0	18.5
G	Wholesale and retail trade; repair of motor vehicles and motorbikes	263	28.5	125	13.6	206	22.3	121	13.1	62	6.7	57	6.2	88	9.5	922	100.0	10.3
H	Transport and warehousing	399	27.7	200	13.9	265	18.4	207	14.4	112	7.8	120	8.3	137	9.5	1440	100.0	16.0
N	Administrative and support service activities	75	11.7	28	4.4	77	12.0	60	9.4	77	12.0	132	20.6	191	29.8	640	100.0	7.1
O	Public administration and defense; compulsory social security	20	22.0	13	3.0	37	8.6	39	9.0	60	13.9	78	18.1	185	42.8	432	100.0	4.8
Total (N = 8974)		1883	21.0	857	9.5	1355	15.1	978	10.9	705	7.9	735	8.2	898	10.0	6115		68.1

FTA (%) = (Fatal Accidents of categories/Total Fatal Accidents) x 100; N number of fatal accidents; %(Id) percentage of fatal accidents with regard to Id.

Table 10
Distribution of fatal accidents by employment status and length of service.

Length of service	Employment status													
	Full-time permanent contracts		Part-time permanent contracts		Indefinite-term contracts, permanent discontinuous		Full-time temporary contracts		Part-time temporary contracts		Other employment relationships		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
<1 month	107	1.3	16	0.2	38	0.4	1070	12.5	106	1.2	0	0	1337	15.6
1–3 months	76	0.9	6	0.1	27	0.3	496	5.8	57	0.7	1	0.0	663	7.8
4–12 months	304	3.6	37	0.4	44	0.5	778	9.1	87	1.0	1	0.0	1251	14.6
1–2 years	456	5.3	40	0.5	21	0.2	248	2.9	33	0.4	0	0	798	9.3
3–4 years	693	8.1	48	0.6	27	0.3	169	2.0	22	0.3	2	0.0	961	11.2
5–10 years	1309	15.3	53	0.6	39	0.5	89	1.0	8	0.1	2	0.0	1500	17.6
11–30 years	1614	18.9	45	0.5	31	0.4	35	0.4	10	0.1	1	0.0	1736	20.3
>30 years	290	3.4	3	0.0	1	0.0	1	0.0	6	0.1	0	0	301	3.5
Total	4849	56.7	248	2.9	228	2.7	2886	33.8	329	3.8	7	0.1	8547	100.0

427 accident reports do not present information about employment status. N number of fatal accidents; % percentage of the total fatal accidents.

Table 11
Distribution of fatal accidents by age and gender in fatal accidents with length of service ≤3 months and Full-time temporary contracts.

Age (years)	Gender			
	Male		Female	
	N	%	N	%
16–19	12	0.8	1	0.1
20–24	78	5.0	9	0.6
25–29	110	7,0	12	0.8
30–39	301	19.2	30	1.9
40–49	460	29.4	34	2.2
50–59	428	27.3	14	0.9
60–69	71	4.5	5	0.3
>70	1	0.1	0	0

N number of fatal accidents; % percentage of the total fatal accidents.

Table 12
Distribution of fatal accidents by CNAE with highest fatal accident rate and Risk Assessment and Distribution of fatal accidents by Health and Safety preventive organization and Risk Assessment.

CNAE	Risk assessment				Health and Safety preventive organization	Risk assessment			
	YES		NO			YES		NO	
	N	%	N	%		N	%	N	%
Agriculture, livestock, forestry, and fisheries	356	37.4	596	62.6	Entrepreneurial assumption	122	63.5	70	36.5
Manufacturing Industry	414	30.2	955	69.8	Own prevention service	19	33.9	37	66.1
Construction	471	28.4	1185	71.6	External prevention service	369	37.3	621	62.7
Wholesale and retail trade; repair of motor vehicles and motorbikes	331	35.9	591	64.1	Designated workers	95	19.2	401	80.8
Transport and warehousing	451	31.3	989	68.7	Joint prevention service	2037	31.6	4411	68.4
Administrative and support service activities	163	25.5	477	74.5	No preventive organization	226	83.4	45	16.6
Public administration and defense; compulsory social security	203	47.0	229	53.0	Various types of organization	72	13.8	448	86.2

N number of fatal accidents; % percentage of the total fatal accidents.

the first hour of the working day, with young male laborers. Cluster 2 contains most of the samples (79,8 %), presenting samples mainly with fatal accidents in their own workplace, the deviation variable is falls or loss of machine control, with older laborers than the other group. Cluster quality, following the model of silhouette measure of cohesion and separation of Rdusseeun & Kaufman [74], was acceptable.

The number of fatal accidents in the period under study reported by the database was 8984 (total accidents 7,421,073). Throughout this period, the number of fatal accidents follows a normal statistical distribution [$W(13) = 0.918$ $p = 0.233$ (Shapiro-Wilk)]. A cluster analysis was carried out using as a reference the year with the number of fatal accidents (693) closest to the average number of fatal accidents in the period of study (690.31). The results of the analysis showed the same predictor variables, as well as a partition of the samples into 2 groups with the same structure as the results of the analysis conducted for all fatal accidents throughout the period of

Table 13
Distribution of fatal accidents by accident location and usual work.

Accident location	Usual work					
	YES		NO		Total	
	N	%	N	%	N	%
Usual workplace	3457	38.5	185	2.1	3642	40.6
Moving between work areas	2405	26.8	151	1.7	2556	28.5
Going to or coming from the worksite	113	1.3	1735	19.3	1848	20.6
Different workplace	860	9.6	68	0.8	928	10.3
Total	6835	76.2	2139	23.8	8974	100.0

N number of fatal accidents; % percentage of the total fatal accidents.

study. Considering this result, this year (2016) was selected as the reference year for the development of a model to predict the effect of the variables on the likelihood of a fatal accident. A logistic regression with the same predictive variables of the cluster analysis was performed to develop a predictive model of the likelihood of a fatal accident. The categories of the variables of the cluster analysis were transformed considering the participation of the samples in cluster composition for each category of the variables, and the requirements to perform the logistic regression. Table 17 shows the independent variables and categories used in the development of the model. The dependent variable (Fatal Accident) assumes the value 1 when the occupational accident is a fatal accident and otherwise 0. Equation (1) shows the proposal regression model (logistic model).

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 * T5_{FIRST} + \beta_2 * T5_{INITIAL} + \beta_3 * T5_{OTHERS} + \beta_4 * P1_{GENDER} + \beta_5 * P2_{NEW\_AGE} + \beta_6 * B1_{CONSTRUCTION} + \beta_7 * B1_{MANUF} + \beta_8 * B1_{TRANSPORT} + \beta_9 * B1_{OTHERS} + \beta_{10} * B3_{SHORT} + \beta_{11} * B3_{MEDIUM} + \beta_{12} * B3_{LARGE} + \beta_{13} * B5_{NEW\_EMPLOYMENT\ STATUS} + \beta_{14} * B6_{RISKASSESSMENT} + \beta_{15} * C1_{WORK} + \beta_{16} * C2_{USUAL\ WORK} + \beta_{17} * C4_{MACHINE} + \beta_{18} * C4_{FALL} + \beta_{19} * C4_{OTHERS} \quad (1)$$

Hence $\ln\left(\frac{p}{1-p}\right)$ is the logit, and β_i the regression coefficients.

Initial variables are in lower case and new variables generated from the initial variables are in upper case. All variables used in the model are in bold.

Regression results show that the model was statistically significant [Chi-Square = 686.64, df = 8 and p < 0.001 (<0.05)] (Omnibus Test of Model Coefficients), and it explained 6.5 % of the variability of fatal accident (Nagelkerke R2 coefficient). P1_GENDER, C2_USUALWORK, T5_INITIAL, T5_FIRST, P2_NEWAGE, B1_TRANSPORT, B5_PERMANENT, C4_MACHINE, C4_FALL, and Intercept were significant predictors of fatal accident at the 5 % level (Wald value > 5, and p < 0.05 for all these predictor variables). The other predictor variables were not significant.

Although T5_INITIAL, and B1_MANUF were not statistically significant, they were included in the model because the manufacturing sector is one of the sectors with the highest number of accidents in Spain, and the number of accidents during the first hours of the working day is very high with respect to the rest of the working day (Table 18). The model was fitted to the data (Hosemer and Lemeshow Test [Chi-square = 21.235, df = 8 p = 0.0 7(>0.05)]). The model correctly predicted 57.2.% of cases where there was no fatal accident and 83.8 % of cases where there was a fatal accident, giving an overall percentage correct prediction rate of 57.2.%. Equation (2) shows the proposal predictor model for fatal accidents (logistic model).

$$\ln\left(\frac{p}{1-p}\right) = logit = -8.33 + 1.592_1 * P1_{GENDER} - 0.603 * C2_{USUALWORK} - 0.279 * T5_{INITIAL} - 0.159 * T5_{FIRST} + 1.1 * P2_{NEWAGE} + 1.002 * B1_{TRANSPORT} - 0.229 * B5_{PERMANENT} + 0.808 * C4_{MACHINE} - 0.259 * C4_{FALL} - 0.154 * B1_{MANUF} \quad (2)$$

P1_GENDER, P2_NEWAGE, B1_TRANSPORT, and C4_MACHINE, variables have a positive and statistically significant impact (β_i >0, Odds Ratio>1, p value < 0.05) that increase the likelihood of occurrence of a fatal accident. The other variables have a negative impact.

The proposed logistic regression model could be used to calculate the likelihood of a fatal occupational accident occurring in Spain in certain cases. For instance, to assess the likelihood of a fatal occupational accident occurring for a male over 40 years old, in the transport sector without a permanent contract, not in the first hour of the working day, out of his usual work, with loss of control of the machine, according to equation (2):

$$\ln\left(\frac{p}{1-p}\right) = logit = -8.33 + 1.592 * 1 - 0.603 * 0 - 0.279 * 0 - 0.159 * 0 + 1.1 * 1 + 1.002 * 1 - 0.229 * 0 + 0.808 * 1 - 0.259 * 0 - 0.154 * 0 = -3.828 \quad (3)$$

And the likelihood could be calculated from equation (3):

Table 14
Distribution of fatal accidents by physical activity and deviation.

Deviation	Physical activity																			
	No information		Machine operations		Work with hand tools		Transport or loading equipment		Handling objects		Manual transport		Movement		Being present		Other activity		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
No information	0	0.0	0	0.0	0	0.0	2	0.0	0	0.0	0	0.0	2	0.0	0	0.0	0	0.0	4	0.0
Electricity, explosion, fire	0	0.0	22	0.2	55	0.6	10	0.1	63	0.7	8	0.1	36	0.4	14	0.2	2	0.0	210	2.3
Dump, escape	1	0.0	8	0.1	19	0.2	6	0.1	11	0.1	0	0	63	0.7	10	0.1	0	0.0	118	1.3
Fall, slide	0	0.0	66	0.7	208	2.3	47	0.5	165	1.8	25	0.3	188	2.1	43	0.5	1	0.0	743	8.3
Loss of machine control	0	0.0	135	1.5	107	1.2	2877	32.1	124	1,4	24	0.3	381	4.2	36	0.4	0	0.0	3684	41.1
Falls involving people	0	0.0	32	0.4	149	1.7	28	0.3	139	1.5	20	0.2	399	4.4	16	0.2	0	0.0	783	8.7
Voluntary body movement	0	0.0	37	0.4	24	0.3	10	0.1	33	0.4	4	0.0	48	0.5	12	0.1	0	0.0	168	1.9
Involuntary body movement	0	0.0	1	0.0	0.0	0.0	0.0	0.0	8	0.1	5	0.1	6	0.1	3	0.0	0	0.0	23	0.3
Shock or jolting action	0	0.0	2	0.0	15	0.2	11	0.1	12	0.1	0	0.0	58	0.6	22	0.2	0	0.0	120	1.3
Others	0	0.0	75	0.8	304	3.4	353	3.9	272	3.0	104	1.2	1533	17.1	475	5.3	5	0.1	3121	24.8
Total	1	0.0	378	4.2	881	9.8	3344	37.3	827	9.2	190	2.1	2714	30.2	631	7.0	8	0.1	8974	100.0

N number of fatal accidents; % percentage of the total fatal accidents.

Table 15
Distribution of fatal accidents by deviation and injury.

Injury	Deviation											
	No information	Electricity, explosion, fire	Dump, escape	Fall, slide	Loss of machine control	Falls involving people	Voluntary body movement	Involuntary body movement	Shock or jolting action	Others	Total %	Total N
No information	1	0	0	1	0	0	0	0	1	0	0.0	3
Wounds, superficial injuries	0	0	0	4	9	2	2	0	22	0	0.4	39
Crushed bones	0	0	0	13	35	27	2	0	1	0	0.9	78
Dislocations, sprains, and strains	0	0	0	0	2	0	0	0	0	0	0.0	2
Amputations	0	1	0	3	21	1	8	0	0	1	0.4	35
Concussions and internal injuries	0	12	1	227	528	246	36	1	36	6	12.2	1093
Burns	0	53	4	3	22	0	3	0	0	0	0.9	85
Poisonings and infections	0	0	53	0	1	0	1	0	6	0	0.7	61
Drowning and asphyxiation	0	9	54	37	95	62	29	1	7	6	3.3	300
Effects of noise. Vibration and pressure	0	0	0	0	0	0	0	0	0	0	0.0	0
Extreme temperature Effects	0	3	0	0	0	2	0	0	0	10	0.2	15
Psychic trauma, traumatic shock	0	90	0	1	7	2	0	0	3	1	1.2	104
Multiple lesions	2	40	6	454	2938	428	78	5	37	4	44.5	3992
Heart attacks, strokes, and other nontraumatic diseases	1	2	0	0	26	13	9	16	7	3091	35.3	3165
Other injuries	0	0	0	0	0	0	0	0	0	2	0.0	2
Total %	0.0	2.3	1.3	8.3	41.1	8.7	1.9	0.3	1.3	34.8	100.0	8974
N	4	210	118	743	3684	783	168	23	120	3121	8974	

N number of fatal accidents; % percentage of the total fatal accidents.

Table 16
Distribution of fatal accidents by injury and body part injured.

Body part injured	Injury																
	No information	Wounds, superficial injuries	Crushed bones	Dislocations, sprains, and strains	Amputations	Concussions and internal injuries	Burns	Poisonings and infections	Drowning and asphyxiation;	Effects of noise. Vibration and pressure	Extreme temperature Effects	Psychic trauma, traumatic shock	Multiple lesions	Heart attacks, strokes, and other nontraumatic diseases	Other injuries	Total	
																N	%
Not specified	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.0
Head	1	6	36	0	6	629	1	0	0	0	1	2	204	364	0	1250	13.9
Neck	0	9	10	0	0	13	0	0	4	0	0	0	24	0	0	60	0.7
Back, including spine and vertebrae	0	0	2	1	0	7	0	0	0	0	0	0	9	0	0	19	0.2
Trunk and organs	1	15	7	0	5	138	3	2	83	0	0	2	158	2786	0	3200	35.7
Upper limbs	0	2	1	0	6	1	0	1	0	0	0	0	4	0	0	15	0.2
Lower limbs	0	5	7	0	8	2	0	0	0	0	0	0	8	0	0	30	0.3
Whole body and multiple parts	0	2	15	1	10	303	81	58	213	0	14	100	3585	14	0	4396	49.0
Other parts of the body not mentioned	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	0.0
Total N	3	39	78	2	35	1093	85	61	300	0	15	104	3992	3165	2	8974	100.0
%	0.0	0.4	0.9	0.0	0.4	12.2	0.9	0.7	3.3	0.0	0.2	1.2	44.5	35.3	0.0	100.0	

N number of fatal accidents; % percentage of the total fatal accidents.

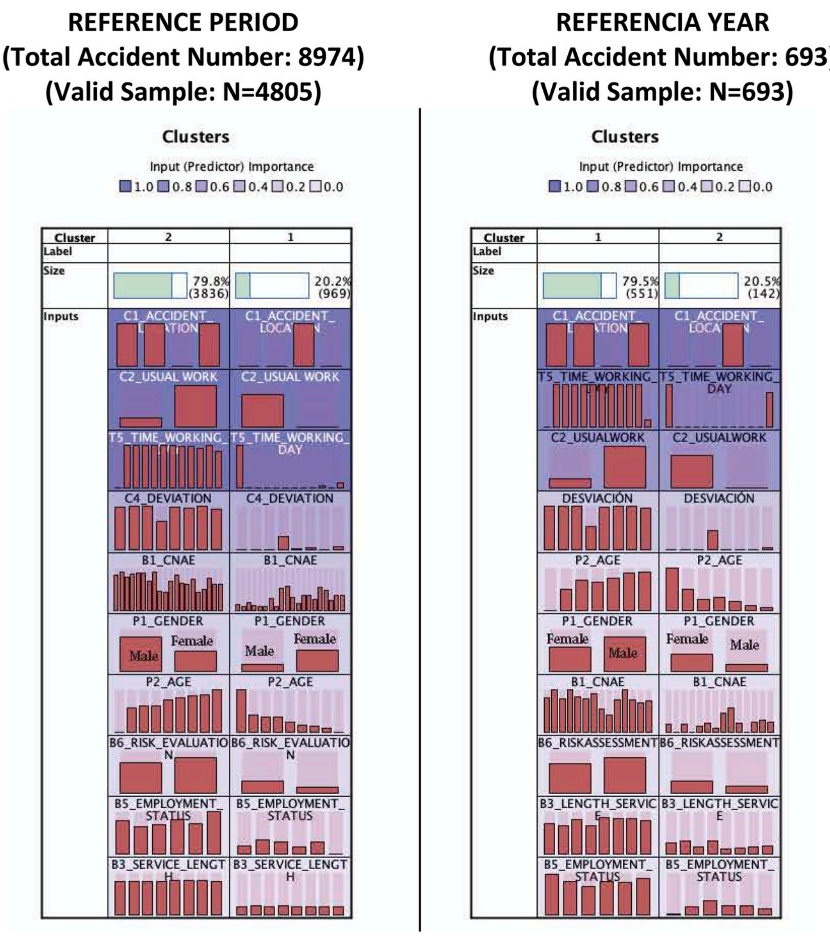

Fig. 4. Cluster results: Input Predictor importance variables and frequency of fatal accidents according to the selected variables and their respective categories within each cluster.

$$p = \frac{e^{logit}}{1 + e^{logit}} = \frac{e^{-3.828}}{1 + e^{-3.828}} = 0.0212 \tag{4}$$

This means (equation (4)) that the likelihood of a fatal accident in the described conditions could be around 2.12%.

5. - Discussion

The study shows a significantly higher number of fatal accidents in men than in women. An overview of the proposed prediction model shows that the P1_GENDER variable has a positive statistically significant impact and produces the highest increase (1.592) in the logit, and therefore the highest increase (4.915) in the odds ratio. This result is in line with those obtained in other countries [57,59,96]. Likewise, the result, which could be more deeply analyzed if data were available on the positions held by men and women in each sector, reflects the need for specific information and harder training programs on occupational risk prevention for male workers [97–99].

An analysis of the evolution over time of fatal accidents according to the CNAE (Table 3) shows that the economic sector with the highest number of fatal accidents is the construction sector, as in other research on national studies [42,45]. If we look at the evolution of the data during the period of study for the construction sector, we can see a decrease in the accident rate in the construction sector during the years of the economic crisis (2012–2016), reinforcing the importance of this sector both in the economy and in the occupational accident rate.

The construction sector is followed by the "Transport and warehousing" sector and the "Manufacturing Industry" sector, the latter heading encompassing a multitude of productive sectors: textiles, metal, food industry, etc. In 2020 there is a reduction in the accident rate in most industrial sectors, coinciding with the confinement due to the COVID'19 epidemic, in line with data from other research [100,101]. This decline is probably due to teleworking and a reduction in face-to-face interactions but not to an improvement in the preventive management of companies [102]. Also noteworthy is the increase in the accident rate in the "Manufacturing Industry"

Table 17
Logistical regression model: Independent predictor variables.

Variable	Type	Values
T5: Time of the working day	Qualitative	For the analysis this variable was recoded into the following three dummy variables: T5_FIRST, T5_INITIAL and T5_OTHERS.
T5_FIRST	Dummy	Assumes the value 1 if the worker has the accident in the first hour of the working day and otherwise 0.
T5_INITIAL	Dummy	Assumes the value 1 if the worker has the accident in the second, third and fourth hour of the working day and otherwise 0.
T5_OTHERS	Dummy	Assumes the value 1 if the worker has the accident in the rest of hours of the working day and otherwise 0 (Reference category)
P1: Gender	Dummy	Assumes the value 1 when the worker is male and 0 when the worker is female.
P2: Age	Qualitative	For the analysis this variable was recoded into the new variable: P2_NEW_AGE
P2_NEW_AGE	Dummy	Assumes the value 1 if the worker's age is 40 years or older and otherwise 0.
B1: CNAE	Qualitative	For the analysis this variable was recoded into the following four dummy variables: B1_CONSTRUCTION, B1_MANUF, B1_TRANSPORT and B1_OTHERS.
B1_CONSTRUCTION	Dummy	Assumes the value 1 if the employer is classified in the construction sector and otherwise 0.
B1_MANUF	Dummy	Assumes the value 1 if the employer is classified in the manufacturing industry sector and otherwise 0.
B1_TRANSPORT	Dummy	Assumes the value 1 if the employer is classified in the transport and warehousing sector and otherwise 0.
B1_OTHERS	Dummy	Assumes the value 1 if the employer is classified in other economic sectors and otherwise 0 (Reference category)
B3: Length of Service	Qualitative	For the analysis this variable was recoded into the following three dummy variables: B3_SHORT, B3_MEDIUM and B3_LARGE
B3_SHORT	Dummy	Assumes the value 1 if the length of service is until 12 months and otherwise 0.
B3_MEDIUM	Dummy	Assumes the value 1 if the length of service is between 1 and 10 years and otherwise 0.
B3_LARGE	Dummy	Assumes the value 1 if the length of service is more than 10 years and otherwise 0 (Reference category)
B5: Employment status	Qualitative	For the analysis this variable was recoded into the new dummy variable: B5 N_ Employment status
B5_N_EMPLOYMENT STATUS	Dummy	Assumes the value 1 if the worker has a permanent contract and otherwise 0.
B6: Risk assessment	Dummy	Assumes the value 1 when the company has a risk assessment available and 0 when it is not available
C1: Accident location	Qualitative	For the analysis this variable was recoded into new dummy variable: C1_WORK
C1_WORK	Dummy	Assumes the value 1 if the accident occurs in a workplace or moving between workplaces and otherwise 0.
C2: Usual work	Dummy	Assumes the value 1 when the worker is carrying out his/her usual work and 0 when the worker is not carrying out it.
C4: Deviation	Qualitative	For the analysis this variable was recoded into the following three dummy variables: C4_MACHINE, C4_FALL and C4_OTHERS
C4_MACHINE	Dummy	Assumes the value 1 when the accident has occurred due to a deviation by loss of machine control and otherwise 0.
C4_FALL	Dummy	Assumes the value 1 when the accident has occurred due to a deviation by fall, slide and falls involving people and otherwise 0.
C4_OTHERS	Dummy	Assumes the value 1 when the accident has occurred due to other type of deviation and otherwise 0 (Reference category)

Table 18
Logistic regression model results.

	β_i	Std.E.	Wald	df	Sig.	e^{β_i}	95 % C.I. for e^{β_i}	
							Lower	Upper
P1_GENDER	1.592	0.133	**142.911**	1	**<.001**	**4.915**	3.786	6.381
C2_USUALWORK	−0.603	0.114	**27.811**	1	**<.001**	**0.547**	0.437	0.685
B6_RISKASSESSMENT	0.11	0.083	1.76	1	0.185	1.117	0.949	1.314
T5_INITIAL	−0.279	0.084	**10.93**	1	**<.001**	**0.756**	0.641	0.893
T5_FIRST	−0.159	0.151	1.118	1	0.29	0.853	0.635	1.146
P2_NEW_AGE	1.1	0.09	**148.602**	1	**<.001**	**3.003**	2.516	3.583
B1_MANUF	−0.154	0.112	1.901	1	0.168	0.857	0.689	1.067
B1_TRANSPORT	1.002	0.098	**104.242**	1	**<.001**	**2.724**	2.247	3.301
B5_PERMANENT	−0.229	0.08	**8.296**	1	**0.004**	**0.795**	0.68	0.929
C4_MACHINE	0.808	0.086	**88.439**	1	**<.001**	**2.243**	1.895	2.654
C4_FALL	−0.259	0.116	**5.018**	1	**0.025**	**0.772**	0.615	0.968
Intercept	−8.33	0.186	**2009.632**	1	**<.001**			

sector and in the "Agriculture, livestock, forestry, and fishing" sector in 2020. This aspect should be analyzed in future work to validate whether there is any causality with an increase in hours worked or an increase in the pace of work, because of trying to make up for the production lost during the confinement. In this line, it is also interesting to highlight the increase in mortality in the years 2020 and 2021 in the sector "Health and social work activities", doubling the values of the historical series. If we specifically analyse the causes of death under this heading in the years 2020 and 2021, 39 deaths of the 78 (50 %) registered were due to COVID'19 [103,104].

A closer look at the agricultural sector shows that 58 accidents correspond to people over 60 years of age and 162 accidents to workers between 50 and 59 years of age, which represents 52.3 % of the total. These results are in line with Thelin [21] and Nag [105] and show the need for greater control by the labour authorities and a need to promote a culture of occupational risk prevention by the agricultural sectoral organizations.

Regard the accident location, the considerable decrease in both accidents in itinere and traffic accidents is justified by the confinement and teleworking during the confinement by COVID' 19 as scientific literature points out [106–108]. If subcategory "Road haulage and removal services" was analyzed, road accidents account for 55.5 % of the total (588/1060) and 66 % of movement between different workplaces (527/799), so it would be necessary to promote training and information on the risks involved in road transport through more general campaigns such as those developed for the population by the Directorate General of Traffic or similar agencies as recommended by other studies [109–112]. An analysis of the cluster analysis results could indicate that accident location is an important variable in classifying fatal accidents.

The distribution of fatal accidents respect to the days of the week shows three situations: a reduction on Saturdays and Sundays where work activity is reduced for most of the working population, similar values from Tuesday to Friday, and a higher percentage on Mondays (1704 accidents and 19.0 % of the global). This situation is not related to the so-called 'Monday effect' [64] since a fatal accident is not a minor accident that could be reported later, but it may reflect physical fatigue or a breakdown in work routine after the weekend [40].

Regard the daytime, the accident rate is not uniform. By afternoon accident rate is lower, and the highest percentages are presented between 10:00 and 12:59 (7.2 %, 7.0 %, and 7.4 %); period follows the workers' usual meal break as the results from the research of Suárez-Cebador et al. [25]. Therefore, it may be necessary to introduce control policies on re-starting the activity.

Finally, about the time of the working day, between the first hour and the following 2 hours, up to 36.9 % of fatal accidents occur. The proposed predictor model points out T5_INITIAL variable with a statistically significant impact. T5_FIRST was not identified with a statistically significant impact, but this variable was included in the model to link the variable to the event of interest modelled [113]. It is paradoxical because theoretically, workers are fresher when they start their working day, but it could be an excess of confidence or a desire to do more work at the beginning of the day. Huang and Hinze [114] and Zermane et al. [23] consider that these results may be an indication of a failure to perform routine tasks at the start of the working day. Supervisors or managers should check that no changes have taken place at the workstation during the night, as well as give reminder talks on safety and health rules. This is an issue that should be highlighted in the development of health and safety practices in companies, such as a meeting at the beginning of the working day where, in addition to the work specifications, a brief reminder of the health and safety measures of the workstations is given.

The results of the distribution of accidents by personal variables are in line with those of other studies such as Chang and Tsai in Taiwan [55] or Farrow & Reynolds in the UK [115], where the accident rate is higher among younger and inexperienced workers, but fatal accidents happen to older workers. Some authors claim that this situation is because older workers find it difficult to adapt to new jobs or new job realities [116], while other authors justify these results by an overconfidence due to age and experience associated with the job [117,118]. The proposed predictor model detects the P2_NEWAGE variable with a statistically significant positive impact (the second highest positive impact). Regarding the distribution between men and women, the results must be the source for developing sectoral and/or company policies with the purpose of limiting the accident rate of workers in women between 40 and 49 and men 50–59 age groups (and the immediately higher). Possible measures could include the rotation of regular tasks with administrative, control and/or sorting and cleaning tasks or the reduction of working hours [27,119].

The analysis of the business variables findings is in line with the conclusions of other research [120,121], where the lack of resources of small size enterprises makes it more complex to comply with occupational safety and health regulations, leading to more unsafe working environments that generate more possibilities for accidents to occur [122].

The highest number of fatal accidents occurred in "Full-time permanent contracts" (56.7 %), followed by "Full time temporary contracts" (33.8 %). The proposed predictor model identifies the B5_PERMANENT variable with a statistically significant impact. It should be noted that 15.6 % of fatal accidents occur in workers with less than one month of experience in the company, reaching a value of 23.4 % for workers with three months of experience. In fact, 215 people died on their first day of work in the company. These findings are consistent with the obtained by Szóstak [65], so that would be prior health and safety training necessary, even before the start of the activity in the company (online or similar).

If we compare the type of Health and Safety preventive organization and the not existence of a risk assessment in fatal accidents, we can see that the "Designated workers" management system reaches a value of 80.8 %, although other more common options, and in theory with greater resources, such as "Own prevention service", "External prevention service" and "Joint prevention service" show values of between 62 and 66 %. This leads us to think that risk assessment in companies should be carried out and reviewed much more regularly by both internal and external personnel with training in occupational risk prevention, as has also been concluded by other authors such as Carrillo-Castrillo et al. [16] and Pichio et al. [123].

An analysis of fatal accidents by accident location and if they were carrying out their usual work shows that the great majority of accidents (except for accidents in itinere) will involve workers carrying out their usual work. The proposed predictor model finds the C2_USUALWORK variable with a statistically significant impact. This finding is related to proposals in view of the results of other variables, such as the need to update risk assessments, specific training for each job, and greater control by managers and supervisors [124].

Of the 3344 accidents of the physical activity "Transport or loading equipment", 2877 resulted in a fatal "Loss of machine control" deviation. Of the 2877 fatal accidents, 2492 were traffic accidents (1503 in itinere, 986 in movement between workplaces and 3 in workplaces), and 385 were non-traffic accidents. These data allow us to advocate the need to develop exhaustive maintenance programs for transport machinery, as well as the development of recycling programs for training in the handling of vehicles, machines, and other handling elements [125,126].

The main deviation that leads to an accident is "Loss of machine control" with 41.1 % of the total fatal accidents, similar results to those of Santos et al. [42] in Portugal. Finally, the deviation "Others" shows 24.8 % of the global fatal accidents. C4_MACHINE and

C4_FALL are variables with significant statistical impact reported by the proposed predictive model. Perhaps it would be necessary to extend the coding referring to the variable "Deviation" and allow this information held on the category "Others" to be more detailed and serve to learn from the accidents that occur in the preventive improvements. The low percentage of explanation of the variability of fatal accidents of the proposed predictive model (6.3 %) can be explained by the grouping of samples in fields without a specific description.

The main "Body part injured" corresponds to "Whole body and multiple parts" and "Trunk and organs" followed by "Head" injuries. These three categories account for 98.6 % of the fatal accidents. These results should be considered for a review by the health and safety prevention services of the suitability and effectiveness of collective and individual protective equipment at the workplace.

If we analyse the sub-categories corresponding to "Trunk and organs", we can distinguish a sub-category called "Thoracic region, including organs". 2781 cases belong to the area where the heart is located. If we analyse their evolution in the period of study, we find a fluctuation of around 200 occupational deaths because of this typology (264 deaths in the year 2009 and 229 deaths in the year 2021, reaching its lowest peak with 169 deaths in the year 2012). These values allow us to affirm "Heart check-ups" should be considered as an obligated checkpoint in the normative medical reviews, in line with indications from other research in high-stress or high-responsibility professions, such as health professionals [127] or police officers [128].

6. Conclusions

The article discussed fatal accidents at work that occurred in Spain during 2009–2021. The purpose of this research was to identify what kinds of accidents occur and analyse the relationship between the variables associated with fatal accidents to provide a framework for improving safety practices and providing a valuable reference for all agents involved in health and safety at work. A total of 8974 workers died in the period of study without achieving a reduction in mortality over time, except for the hardest period of the Spanish economic crisis.

The study not only provides a statistical description of the analyzed data but also presents a classification of fatal accidents into homogeneous groups, as well as a proposal for a predictive model that could be used to estimate the likelihood of a fatal occupational accident as a result of a specific circumstances in Spain.

The importance of the Construction sector and the Transport and warehousing sector in the Spanish economy is also reflected in the high occupational mortality rate. The autonomous communities with greater economic development have higher mortality rates, except for the Basque Country. COVID-19 has had a positive influence on the reduction of accidents in itinere during the year 2020 but has led to an increase in mortality in the year 2020 and 2021 for workers in the sector of Health and social work activities.

The first 3 hours of the working day, the meal breaks, and Monday have the highest accident rates in relation to the variables time of the working day, the daytime, and the day of the week. These data require improved control by managers and supervisors during these temporary periods.

Fatal accidents at work are more common in males, especially in workers between 40 and 59 years old. This should focus the efforts of company prevention services on retraining or combining it, as far as possible, with other tasks with a lower level of exposure to risk, such as administrative or maintenance tasks.

Companies with less than five workers, one of the most common types in the Spanish economy, have the highest percentage of fatal accidents, which should focus governmental and sectoral policy efforts on health and safety training. Length of service-fatality is not uniform, but approximately 23 % of accidents have occurred in the first three months on the job, so that would be prior health and safety training necessary, even before the start of the activity in the company (via online or similar).

When accidents occur in the normal workplace, they almost always happen in the course of their normal work, which in some way calls for an update of workplace risk assessments to identify new or incorrectly assessed risks.

Loss of machine control is the deviation that causes the highest occupational mortality. Regard on variable injuries, in the first place, occupational deaths are usually caused by Multiple lesions that correspond to cases where the victim suffers two or more types of injury of similar severity, followed by Heart attacks, strokes, and other nontraumatic diseases.

6.1. Limitations

Among the main limitations and difficulties encountered in carrying out research on fatal accidents in Spain must be highlighted the following. Firstly, information was lacking on some accident reports, and then data were grouped under headings as "No information", for example, in the variable "Time of the working day". The second limitation is related to headings for some variables that group too much data together and do not allow for a more detailed analysis to learn from accidents and to be able to design better preventive measures, for example, the heading "Other" in the variable "Deviation".

The third limitation is that accident reports do not present data on individuals for some variables that could have explanatory power at statistically significant levels, such as the methods of organization of work, the level of education completed, the level of education of workers, the training and experience of the worker in the job, the health and safety training, or system of performance evaluation, achievement of objectives and rewards.

The fourth limitation is that specific incidence rates cannot be calculated for each variable studied as data on hours worked are not available.

6.2. Future research

As seen in the literature review, there are not many studies on fatal accidents at the country level, so this would be an interesting future line of work. Also, certain variables should also be deeply analyzed to provide further details and thus create suggestions to reduce the accident rate. For example, researchers should more deeply analyse the type of deviation “Loss of machine control” because it causes 41.1 % of fatal accidents. Another field of study is related to the influence of the group of injuries “heart attacks, strokes, and other nontraumatic diseases”, which account for nearly 35.3 % of fatal accidents in the sector. It is necessary to establish in which sectors, age groups, companies, etc., occur these types of fatalities to plan preventive medical check-ups, especially on issues related to heart health.

Data availability statement

The data used for the research were requested from the Spanish Ministry of Labour and Social Economy. The authors do not have permission to share data.

CRediT authorship contribution statement

J.L. Fuentes-Bargues: Validation, Methodology, Conceptualization, Investigation, Visualization, Writing - original draft, Writing - review & editing. **A. Sánchez-Lite:** Visualization, Validation, Conceptualization, Investigation, Methodology, Writing - original draft, Writing - review & editing. **C. González-Gaya:** Visualization, Funding acquisition, Writing - review & editing. **M.A. Artacho-Ramírez:** Visualization, Investigation, Writing - review & editing.

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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