IEEJ Journal of Industry Applications
Vol.13 No.6 pp.711–722 DOI: 10.1541/ieejjia.24002974

Paper

Technical Analysis of Occupational Fatal Accidents in Malaysia Using Machine Learning Techniques

Hanane Zermane[*a)] Non-member, Abderrahim Zermane[**] Non-member
Mohd Zahirasri Mohd Tohir[**] Non-member

(Manuscript received March 27, 2024, revised May 19, 2024)
J-STAGE Advance published date : July 19, 2024

With the rapid economic growth of Malaysia, workplace accidents have increased drastically, according to the Department of Occupational Safety and Health (DOSH). This study aimed to determine the patterns in Malaysian workplace fatal accidents. A total of 505 fatal accident cases across 15 industries were analyzed in this study using both qualitative and quantitative methods. These fatality cases were identified and recorded by the DOSH from 2010 to 2020. The data were arranged and coded in Python and analyzed in terms of frequency analysis, Spearman's rank order correlation, eta squared, chi-square, and Cramer's V methods. Furthermore, neuro-linguistic programming was performed for word cloud and sentiment analyses. Finally, a light gradient-boosting machine learning model was used to further understand the causes of fatalities in Malaysia. The results showed that fatal falls from heights were the highest contributor to fatal accidents (32%, n = 161). Workers under contract were more vulnerable to fatal accidents in the construction industry (n = 324, 64%) than other workers. General workers were the most susceptible category to fatal accidents (60%, n = 302). The results from this study provide valuable insights into workplace fatal accident patterns and strategies for their prevention across industries.

Keywords: risk management, neuro-linguistic programming, machine learning, mixed-method analysis, prevention management

1. Introduction

Malaysia has witnessed a conspicuous rise in accident cases over ten years (2010–2020), according to the yearly reports from the Malaysia Department of Occupational Safety and Health. The lowest number of occupational accidents was recorded in 2011, with 2429 accidents, whereas 2019 recorded the highest occupational accident number, with 7981 accidents[(1)]. Companies must report occupational injuries under the Occupational Safety and Health Act of 1994 (Act 514).

The DOSH investigates the accidents reported by employers to determine the underlying causes under the Occupational Safety and Health Act of 1994 (Act 514)[(2)]. There is a noticeable increase in accident numbers, from 2011 to 2020, which requires immediate intervention to help stop the ever-rising accident numbers and prevent the numbers from going higher.

Table 1 illustrates the annual rates of occupational injuries and fatal occupational injuries per 100,000 workers in Malaysia from 2014 to 2022. Similarly, the rate of fatal occupational injuries per 100,000 workers exhibits variations over the same timeframe.

Table 1. DOSH investigated accident cases from 2014 to 2022 (DOSH, 2021)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
Rate of Occupational Injuries	3.1	2.81	2.88	2.93	2.4	2.71	2.18	1.43	2.22
Rate of Fatal Occupational Injuries	4.21	4.84	4.84	4.9	4.14	3.83	2.09	2	2.06

Table 2 presents a comprehensive overview of occupational accidents categorized by sector. Examining the sectors individually, the Manufacturing sector exhibits the highest frequency of accidents, followed by Agriculture, Forestry, and Fishery. Notably, the Construction sector reports a significant number of accidents resulting in Permanent Disability, totaling 8 cases, and fatalities, accounting for 45 cases. The Finance, Insurance, Real Estate, and Business Services sectors also demonstrate a considerable number of accidents.

Understanding the distribution of accidents allows for the development and implementation of sector-specific safety measures, training programs, and regulations to mitigate risks and safeguard the well-being of the workforce in Malaysia. The provided source offers a valuable resource for stakeholders and policymakers in their efforts to create safer working environments and reduce occupational accidents. Most

a) Correspondence to: Hanane Zermane. E-mail: h.zermane@univ-batna2.dz
* Industrial Engineering Department, Faculty of Technology, University of Batna 2
Batna, Algeria
** Safety Engineering Interest Group, Department of Chemical and Environmental Engineering, Faculty of Engineering, Universiti Putra Malaysia
43400 Serdang, Selangor, Malaysia

Table 2. Occupational accident statistics by sector from January to October 2023

Sector	NPD	PD	Death	Total
Hotel and Restaurant	176	0	0	176
Utilities (Electricity, Gas, Water and Sanitary Service)	147	0	4	151
Finance, Insurance, Real Estate and Business Services	554	15	15	584
Construction	106	8	45	159
Transport, Storage and Communication	326	7	9	342
Manufacturing	3,961	175	45	4,181
Wholesale and Retail Trade	145	2	0	147
Public Services and Statutory Authorities	117	2	0	119
Mining and Quarrying	23	1	4	28
Agriculture, Forestry and Fishery	1,020	25	19	1,064
Total	**6,575**	**235**	**141**	**6,951**

Legend: PD: Permanent Disability, NPD: Non-Permanent Disability.

Source: International Policy and Research Development Division, Department of Occupational Safety and Health, Ministry of Human Resources, https://www.dosh.gov.my/index.php/statistic-v/occupational-accident-statistics/occupational-accident-statistic-2023.

studies either looked at one sector, investigated a specific accident or outcome, or focused on a specific target population.

Zermane et al.[3] investigated the factors contributing to fatal falls from heights, whereas Zerguine et al.[4] investigated work-related injuries among foreign workers in the construction industry. Based on machine learning techniques, this study provides a deeper understanding of fatal accident patterns in Malaysia, which industries to focus on, what categories of workers are more vulnerable to fatalities, and what types of accidents impact fatalities most.

2. Literature Review

Very little research focused on fatal accidents in Malaysian workplaces. Several studies have tried to tackle one issue at a time, where some researchers concentrate on behavioral topics, whereas others focus on uncovering the contributing factors to a specific accident type, such as. Other studies focused on a particular sector, such as Ayob et al.[5], Chong and Low[6], Hamid et al.[7], Mohammad and Hadikusumo[8], and Zermane et al.[3][9][10] focused on the construction sector.

Zin and Ismail[11] investigated the behavioral factors associated with safety culture within the construction industry[12]. Surveyed 117 construction workers registered under the Construction Industry Development Board (CIDB). The authors found that management commitment was the most crucial aspect regarding workers' safety behaviors. However, management beliefs and practices were two different things; no matter how much management put belief and high expectations of their commitment to safety, their practices reflected the opposite. Ismail et al.[12] study did not directly help prevent fatal accidents; however, the outcome will help shine the light on what is happening within the management of construction companies. Moreover, they are associated with avoiding accidents by focusing the sample size on the upper administration within the company.

Zakaria et al.[13] focused on individual factors and how they interact with job factors. Results indicated that stress is one of the leading causes of workplace accidents, followed by unsafe acts and the lack of training. Furthermore, the authors did not focus on occupational accidents, whether fatal or nonfatal; unlike this study, Zakaria et al.[13] took a proactive approach to prevent human error in the Malaysian oil and gas industry.

Mohammed and Ishak[14] studied fatal and nonfatal accidents in the Malaysian construction industry. The authors found that fatal accidents impact the construction industry more than nonfatal accidents. Results, however, are consistent with what Ayob et al.[5] found in 2018. Ayob et al.[5], unlike Mohammed and Ishak[14], focused on a fatal accident in the construction industry.

Hamid et al.[7] investigated the causes of fatal accidents in the construction industry. The authors' ideas are similar to Mohammed and Ishak[14]. However, the authors focused on fatal accidents in the construction industry, identical to Ayob et al.[5], Zermane et al.[3], analyzed the contributing factors to 206 fatal falls from height accidents in Malaysia and the United States. Further, managerial/organizational factors such as management's commitment to safety and the lack of work-at-height training and schedules were also critical. Moving further, Zermane et al.[9] conducted a risk assessment to determine the causes behind fatal falls from height accidents.

To conclude, most research that tackled the fatal accidents gap focused on the construction sector since it is the highest contributor to fatal accidents; however, for Malaysians, the manufacturing and the agriculture sectors contribute significantly to fatal accident cases besides the construction sector, according to DOSH[1]. Statistical analysis can uncover helpful information related to a specific accident case which can help determine trends and evaluations of fatalities.

3. Materials

This study collected data from the DOSH public accident database, Malaysia's official occupational safety and health authority[1]. The data covered 2010 to 2020, including 505 fatal accidents (Table 3).

The data was not normalized due to the descriptive nature and the several abnormalities in entering the data into the database. Hence, it was necessary to normalize and extract useful information for data analysis purposes. Helpful information was removed from the summary and added to this study's factors. Table 4 shows the process of removing the information from data in Table 1. An agreement has been achieved between the authors on the variables and categories included. Furthermore, two researchers independently extracted a sample of 20 cases, and a high agreement rate was achieved. Data extraction went as follows; the date column was divided into five more sections (year, weekday, month, day, week) (Table 4).

Eleven factors were extracted from the dataset to analyze the data: Year, Month, Day, Weekday, Employment status, Nationality, Type of Accident, Location, Industry, Activity, and No.of Victims. Each factor contains characteristics that

Table 3. Example of published workplace fatal accident cases by DOSH, Malaysia

Date	Title Case	Location	Summary Case
18/12/2020	A self-employed person was found drowned	Agriculture, Kedah	A self-employed man was found drowned while lying in a rice field
12/12/2020	Deadly workers buried in landslides	Construction, Pahang	A foreign worker died after being buried in a landslide while the victim was monitoring welding work in a pipe.

Table 4. Example of the interpretation of keywords in the case reports

Original form	Keyword	Information
A self-employed man was found **drowned** while lying in a rice field	Self-employed	Employment Status: Self-employed
Agriculture, Kedah	Agriculture, Kedah	Industry + Location
A **self-employed** person was found **drowned**	drowned	Type of Accident: Drown
18/12/2020	18/12/2020	Year + Month + Day + weekday + Week of year
A **foreign worker** died after being **buried** in a **landslide** while the victim was monitoring **welding work in a pipe**.	foreign worker	Nationality: Foreigner
A **foreign worker** died after being **buried** in a **landslide** while the victim was monitoring **welding** work in a pipe.	welding	Activity: Welder

define them (Table 5).

Table 6 indicates the types of accidents used in this study; each type of accident is provided with a definition to help understand the criteria used to determine the types of accidents.

Table 7 indicates the types of activities used in this research; the activities were determined based on the summary of each accident case mentioned in Table 4.

Table 8 illustrates the result of extracting data from accident case reports; The Method in Table 4 was applied to all 505 cases; categories such as; industry, employment status, activity, nationality, no. of victims, year, month, day, weekday, and week were all extracted and used as factors for the data analysis using a python code.

A normality test was applied to determine the numerical data's normality. Frequency analysis was used to explore workplace fatal accidents using different factors. Furthermore, the Mann-Whitney U test and Kruskal Wallis tests were applied to measure the association between polytomous (nominal) and numeric variables (Types of accidents and the number of victims)[15]. Finally, Chi-square and Cramer's V and Phi were used to determine the relationship between the

Table 5. List of factors and categories extracted from the case reports

Factors	Values
Year	2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020
Month	January, February, March, April, May, June, July, August, September, October, November, December
Day	Days of month
Weekday	Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday
Employment status	Self-employed, Contract
Nationality	Local, Foreigner
Type of Accident	Drown, Buried, struck by, Fall, caught in between, Burn, Road accident, Electrocution, Explosion, Asphyxiation, Crushed by, Other.
Location	All 16 Malaysian States, undefined states were marked as other
Industry	Agriculture, Construction, Education, Food and beverages, Forestry, Hotel and Tourism, Manufacturing, Mining, Port, Public Road, Quarry, Railways, Residential area, Retail, Storage area, Transportation, Waste treatment, and Undefined industries were marked as other
Activity	Farmer, General Worker, Welder, Driver, Carpenter, Mechanic, Supervisor, Electrician, Operator, Roofer, Manager, Safety Personnel, Technician, Scaffolder, Other
No. of Victims	1, 2, 3, 4, 5, and 6

categorical variables (Industry and Activity)[16]. When the Cramer's V coefficient between two variables ($P < 0.05$) exceeds 0.1, there is a strong association between those variables[17].

4. Methods

Each accident's cause is described in the description column. The authors used this crucial data with Neuro-linguistic programming (NLP) methodology to develop new features. The authors defined a handmade stopwords list by reviewing the papers in the 'Summary Case' and 'Focus of inquiry' columns, complementing the predefined stopwords in WORDCLOUD. The authors created a pre-processing function to simplify the otherwise complex NLP pre-processing pipeline by lowering the case, tokenizing, lemmatizing, and stemming text before it is processed. After a word has been normalized, stemming removes any common prefixes or suffixes and leaves just the base form of the term[18].

Several inflected words, like "suffering" and "died" are derived from the root word "die" and are used interchangeably in this type of medical discourse. After the summary case had been normalized, a basic feature selection or symptom tokenization was performed. Each token can then be used to create a symptom sparse matrix by inverting the frequency of documents containing those tokens[18]. This study used sentiment analysis of the summary case and the focus of the investigation to determine the severity of the accident cases. Whether a positive or a negative sentiment can indicate the

Table 6. Definition of the type of accident extracted from the case reports

Type of Accident	Definition
Drown	Any accident where the workers drown due to any kind of liquid
Buried	Any accident where the worker is stuck underground while being covered
Struck by	Any accident where the worker gets struck by a foreign object
Fall	Any accident where the worker falls whether from elevation or the same level
Caught in between	Any accident where the worker is caught in between two objects or in something
Burn	Any accident where the worker is exposed to extreme heat
Road accident	Any accident where the worker is exposed to any accident related to Roads or driving
Electrocution	Any accident where the worker is exposed to strong electricity
Explosion	Any accident where the worker is exposed to an explosion
Asphyxiation	Any accident where the worker is in an environment that lacks oxygen
Crushed by	Any accident where the worker is crushed due to a foreign object
Other	Any accident that is not included above

Table 7. Definition of the type of activities extracted from the accident cases

Activity	Definition
Farmer	Any worker who performs farming activities
General Worker	Any worker who performs general activities
Welder	Any worker who performs welding or cutting activities
Driver	Any worker who performs driving activities
Carpenter	Any worker who performs wood-related activities
Mechanic	Any worker that performs any type of vehicle fixing activities
Supervisor	Any worker who performs supervision and team-leading activities
Electrician	Any worker who performs electricity-related activities
Operator	Any worker who operates heavy machinery and factory equipment
Roofer	Any worker who performs roof fixing or building activities
Manager	Any worker who is involved in the upper management of the workplace
Safety Personnel	Any worker who is responsible for the safety of the workplace
Technician	Any worker who performs special technical activities
Scaffolder	Any worker who builds, and dismantles scaffoldings
Other	Add examples here

level of the severity of the accident. A score of 0 indicates a neutral sentiment whereas scores higher than −0.05 and 0.05 indicate a negative and a positive sentiment respectively. Light-GBM is a gradient-boosting system. It uses tree-based learning algorithms to back many interpretable approaches and generates precise and timely outcomes. It can process large datasets, uses little memory, and optimizes through parallel and GPU-based learning[19].

Table 8. Definition of the type of activities extracted from the accident cases

Type of Accident	Drown	Buried
Location	Kedah	Pahang
Industry	Agriculture	Construction
Employment status	Self-employed	Contract
Activity	Farmer	General Worker
Nationality	Local	Foreigner
No. of Victims	1	1
Year	2020	2020
Month	12	12
Day	18	12
Weekday	Friday	Saturday
Week of Year	51	50

5. Results

The primary focus of the frequency analysis was the statistical description of workplace fatal accidents with the different factors of the study (Table 9).

The highest number of workplace fatal accidents over ten years was recorded in 2014 (n = 97, 19%) and 2020 (n = 72, 14%) (Table 9). A fifth of all accident cases recorded was in 2014 (n = 97, 19%), which is twice the average yearly accident number; there was a decline in the number of accidents after that, but then around 2018, it started going up again until 2020, which recorded 14% (n = 72, 14%) of all accident cases. A noticeable increase in fatal accidents was recorded in 2018; the sudden increase in accident numbers almost doubled from (n = 23, 5%) to (n = 52, 10%) accidents in one year. Furthermore, the accident numbers are inconsistent; for example, in 2010, (n = 24, 5%) fatal accidents were reported, then in the following year, the numbers almost doubled, and then an increasingly alarming pattern started from 2011 to 2015 with (n = 64, 13%) accidents (see Fig. 1).

Two months with the most severe accidents, February, and October, accounted for 10% (n = 50) of each recorded fatal accident (Table 7). As for the rest of the months, all had similar accident numbers that ranged from (n = 37, 7%) to (n = 45, 9%) accidents except April (see Fig. 2).

The two days with the most severe accidents were the last day of the week and the first day of working days, Friday, and Monday, respectively (Table 9). Other days of the week recorded similar accident results ranging from (n = 64, 13%) accidents to (n = 72, 14%). Wednesday recorded the lowest accident number, which accounted for (n = 51, 10%) accidents (see Fig. 3).

It is no surprise that the construction industry recorded the highest number of fatal accidents (n = 210, 42%) of all sectors, which is more than double that of the manufacturing sector (n = 102, 20.2%) and significantly higher than agri-

Table 9. Definition of the type of activities extracted from the accident cases

Factors	Frq	%	Factors	Frq	%
Type of accident			**Industry**		
Asphyxiation	13	2.6	Agriculture	70	13.9
Buried	13	2.6	Construction	210	41.6
Burn	7	1.4	Education	4	0.8
Caught in between	55	10.9	Food and beverages	4	0.8
Crushed by	60	11.9	Forestry	20	4.0
Drown	15	3.0	Hotels and Tourism	5	1.0
Electrocution	30	5.9	Manufacturing	102	20.2
Explosion	11	2.2	Mining	3	0.6
Fall	161	31.9	Other	20	4.0
Other	7	1.4	Port	13	2.6
Road Accident	11	2.2	Public road	9	1.8
Struck by	122	24.2	Quarry	8	1.6
			Railways	1	0.2
			Residential area	6	1.2
			Retail	11	2.2
			Storage area	8	1.6
			Transportation	2	0.4
			Waste treatment	9	1.8
Location			**Activity**		
Johor	138	27.3	Carpenter	3	0.6
Kedah	22	4.4	Driver	46	9.1
Kelantan	11	2.2	Electrician	20	4.0
Kuala Lumpur	46	9.1	Farmer	48	9.5
Melaka	11	2.2	General Worker	302	59.8
Negeri Sembilan	4	0.8	Manager	2	0.4
Other	2	0.4	Mechanic	9	1.8
Pahang	45	8.9	Operator	30	5.9
Penang	67	13.3	Other	13	2.6
Perak	30	5.9	Roofer	14	2.8
Perlis	6	1.2	Safety Personnel	1	0.2
Putrajaya	1	0.2	Scaffolder	1	0.2
Sabah	24	4.8	Supervisor	5	1.0
Sarawak	67	13.3	Technician	1	0.2
Selangor	23	4.6	Welder	10	2.0
Terengganu	8	1.6			
Employment status			**Nationality**		
Contract	324	64.2	Foreigner	83	16.4
Self-employed	181	35.8	Local	422	83.6
Year			**Month**		
2010	24	4.8	January	37	7.3
2011	41	8.1	February	50	9.9
2012	25	5.0	March	43	8.5
2013	37	7.3	April	30	5.9
2014	97	19.2	May	44	8.7
2015	64	12.7	June	45	8.9
2016	30	5.9	July	39	7.7
2017	23	4.6	August	45	8.9
2018	52	10.3	September	38	7.5
2019	40	7.9	October	52	10.3
2020	72	14.3	November	43	8.5
			December	39	7.7
Weekday			**Number of victims**		
Friday	91	18.0	1	482	95.4
Monday	91	18.0	2	14	2.8
Saturday	68	13.5	3	5	1.0
Sunday	64	12.7	4	1	0.2
Thursday	72	14.3	6	3	0.6
Tuesday	68	13.5			
Wednesday	51	10.1			

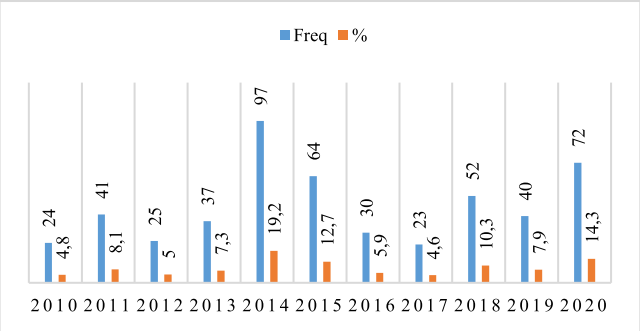

Fig. 1. Frequency of accidents over years (2010–2020)

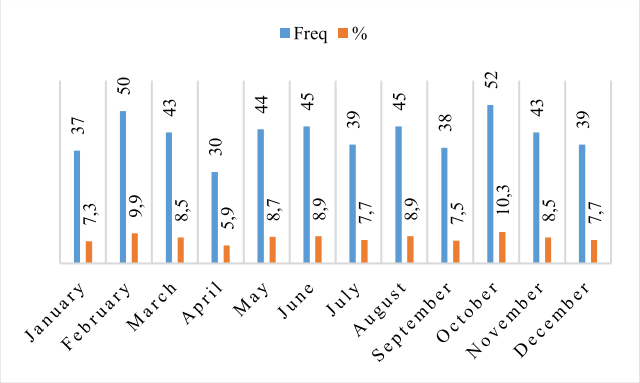

Fig. 2. Frequency of accidents by months

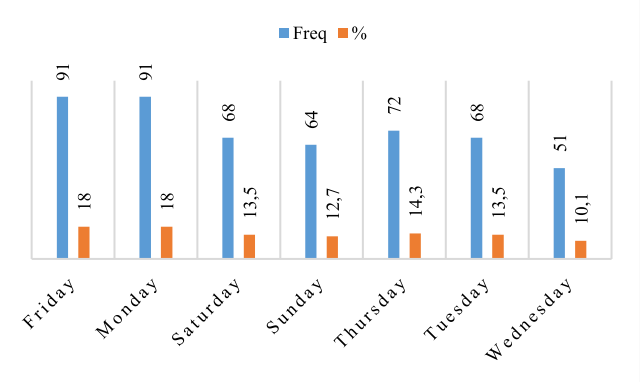

Fig. 3. Frequency of accidents by days

culture (n = 70, 13.9%). This high incidence in construction could be attributed to the inherent risks associated with building activities and the potential for more hazardous work environments. While considerable, the manufacturing sector suggests a need for targeted safety training and compliance enforcement. Other industries, like agriculture, also show notable numbers, indicating the importance of sector-specific safety measures. The data reflects the critical need for implementing rigorous safety protocols and regular monitoring in these high-risk industries to reduce the number of fatalities effectively (see Fig. 4).

The following analysis compares fatality rates per 100,000 employees across three major sectors: agriculture, construction, and manufacturing (see Fig. 5). Employment data for 2023 indicates that approximately 1.87 million individuals were employed in agriculture, around 1.211 million in construction, and about 2.8 million in manufacturing. Notably, the construction sector's workforce includes a substantial proportion of foreign workers, which may influence both the nature of the work and the associated risks. These employment figures are crucial for understanding the context in which the fatality rates were calculated. By relating the absolute fatalities to the total number of employees in each sector, we derive a metric that allows for a comparative analysis of occupational risk across different industries. This approach clarifies which sectors may require stricter safety measures and oversight due to higher relative fatality rates.

The construction sector's fatality rate of 17.34 per 100,000 employees is noticeably higher than those observed in the agriculture and manufacturing sectors, which are 3.74 and 3.64, respectively. This discrepancy can be attributed to the

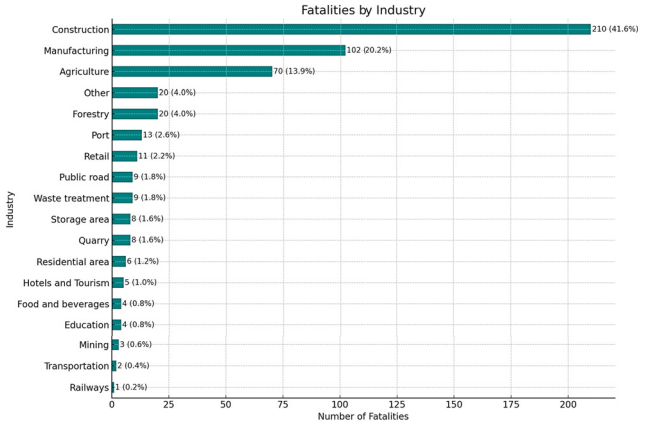

Fig. 4. Fatalities by Industry

Fig. 5. Fatalities per 100,000 Employees by Sector

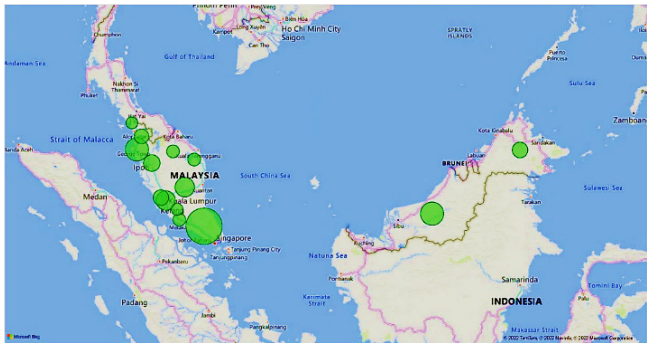

Fig. 6. Geographical representation of workplace

specific hazards that are more prevalent in construction activities, including working at heights, operating heavy machinery, and handling large loads. These activities carry more significant risks, reflected in the higher fatality rate. Conversely, while also posing risks due to the nature of their operations, the agriculture and manufacturing sectors report significantly lower fatality rates. This suggests that the type of work conducted in the construction sector inherently poses more significant threats to worker safety.

Johor recorded the highest number of accidents (n = 138, 27%) of all accidents (see Fig. 6). Penang and Sarawak recorded the second-highest accident numbers (n = 67, 13%) each. Kuala Lumpur, Putrajaya, and Selangor, their surrounding capital, are bound to have more development projects than other cities[20]. However, accidents in those areas were far less than in cities that were thousands of

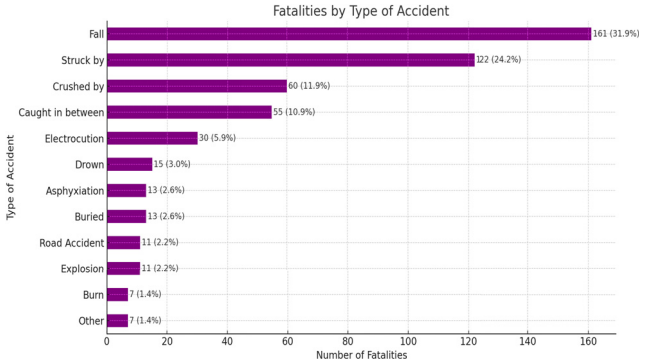

Fig. 7. Fatalities by Type of accident

kilometers away; this can be related to the location of the DOSH main office, the closer the main office, the more DOSH audits that occur, and the opposite applies, the further you are from DOSH main office the more accidents occur. This trend can also be seen in different states, where Putrajaya (where DOSH's main office is located) is the fatal accident's lowest recording state. At the same time, Perak, Sabah, and Kedah recorded higher accident counts.

General workers were the most affected by fatal accidents (60%, n = 302) (Table 9). Farmers and Drivers were the second-highest categories vulnerable to deadly accidents (n = 48, 10%) and (n = 46, 9%), respectively. Road accidents were not included in this analysis unless the worker was at his workplace or on the way to it; with that in mind, the number of accidents recorded by drivers was the third most recorded accident (n = 46, 9%) of all accident cases.

Fatal falls are the most prevalent cause, accounting for nearly a third of all fatal accidents (n = 161, 31.9%) over ten years (Table 9). This highlights a substantial risk associated with working at heights and underscores the importance of fall prevention strategies such as safety harness systems, adequate training, and regular safety audits. The next highest category is accidents caused by being struck by objects (n = 122, 24.2%), suggesting a significant risk from moving or falling objects at worksites. These two types are followed by incidents where workers were caught between (n = 55, 10.9%), pointing to potential issues with machine safety and workspace design. Accidents like electrocutions (n = 30, 5.9%) and explosions (n = 11, 2.2%) are less frequent but still concerning, which calls for strict adherence to electrical safety standards and hazardous materials management. The breakdown of accident types provides essential insights into the most critical areas where safety interventions are urgently needed (see Fig. 7).

Other categories, such as electricians and operators, registered moderate numbers with (n = 20, 4%) and (n = 30, 6%), respectively. Contract workers are more susceptible to fatal accidents than self-employed workers (n = 324, 64%) (Table 9).

Spearman correlation showed no significant association between the number of victims and the dates of the accidents, whether it is days, months, weeks, or years (Table 10). Zerguine et al.[4] concluded that foreign workers who suffered work-related injuries recorded no association with the dates of the accidents.

Table 10. Spearman rank-order correlation coefficient between ordinal columns

	Victims		Year		Day		Week	
	R_s	P-value	R_s	P-value	R_s	P-value	R_s	P-value
Victims	1.000		-0.032	0.467	0.049	0.270	-0.006	0.902
Year	-0.032	0.467	1.000		0.008	0.859	0.066	0.140
Day	0.049	0.270	0.008	0.859	1.000		0.040	0.364
Week	-0.006	0.902	0.066	0.140	0.040	0.364	1.000	

Note: *P<0.05, **P<0.01

Table 11. Effect of the relevant factors on the nationality and employment status using Mann Whitney U test

Relevant factors	Nationality	Employment status
No of Victims	0.932	0.058
Year	0.834	0.576
Day	0.586	0.396
Week of year	0.040*	0.628

Note: *P<0.05, **P<0.01

Table 12. Effect of the relevant factors using Kruskal Wallis test

Relevant factors	Types of accidents	Weekday	Industry	Location	Activity
No of Victims	0.000**	0.659	0.085	0.005**	0.611
Year	0.038*	0.342	0.024*	0.000**	0.001**
Day	0.073	0.533	0.696	0.167	0.213
Week of year	0.623	0.216	0.444	0.294	0.211

Note: *P<0.05, **P<0.01

Mann Whitney U test was applied to determine the effect of the number of victims, the year of the accident, the Day of the accident, and the week of the year on the nationality and the employment status (Table 11). There exists only one significant association between the week of the year and the nationality (P = 0.040).

Kruskal Wallis test was used to determine the effect of the year, day, week of the year, and the number of victims on the types of accidents, weekday, the industry, the location, and the activity of the workers (Table 12). The Kruskal Wallis test shows that there is an effect of the number of victims on the location where the accident occurred (p = 0.005) and the types of accidents (p = 0). In contrast, the year of the accident can affect the type of accident (p = 0.038), the industry (p = 0.024), the location of the accident (p = 0), and the activity performed when the fatality occurred (p = 0.001).

The contingency table was used in this study, and correlation coefficients were measured in Table 13 with 95% confidence intervals. Cramer's V correlation coefficient was selected to measure the correlation between variables with more than 2xn categories. Other variables besides weekdays have moderate to strong correlations; hence, the activity of the worker impacts other factors such as the employment status (p = 0, V = 0.585), the type of accident (p = 0, V = 0.220), and nationality (p = 0.033, V = 0.148).

Table 13. Contingency table for correlation coefficients between factors

Dependent variable	Independent variable	X^2	df.	Sig.	Phi	Cramer's V
Activity	Employment status	186.773	14	0.000**	2.726	0.585
	Nationality	25.166	14	0.033*	0.032	0.148
	Weekday	106.132	84	0.052	0.0518	0.085
	Types of accidents	417.604	154	0.000**	3.447	0.220
	Industry	700.793	238	0.000**	3.885	0.259
	Location	291.216	210	0.000**	0.000	0.108
Industry	Employment status	248.417	17	0.000**	4.392	0.677
	Activity	700.793	238	0.000**	3.885	0.259
	Types of accidents	319.453	187	0.000**	5.409	0.155
	Location	410.427	255	0.000**	2.250	0.145
	Nationality	25.700	154	0.080	0.080	0.131
	Weekday	123.529	102	0.072	0.072	0.084
Employement status	Nationality	7.933	1	0.005**	0.004	
	Industry	248.417	17	0.000**	4.392	
	Location	55.899	15	0.000**	1.260	
	Activity	186.773	14	0.000**	2.726	
	Types of accidents	30.900	11	0.001**	0.001	
	Weekday	5.401	6	0.493	0.493	
Nationality	Industry	25.700	17	0.080	0.080	
	Location	26.182	15	0.036*	0.036	
	Employment status	7.933	1	0.005**	0.004	
	Activity	25.166	14	0.033*	0.032	
	Types of accidents	16.989	11	0.108	0.108	
	Weekday	3.007	6	0.808	0.807	

Note: *P<0.05, **P<0.01

The industry recorded a strong correlation with the Employment status (p = 0, V = 0.677), the Activity (p = 0, V = 0.259), the Types of accidents (p = 0.033, V = 0.155), and the Location (p = 0, V = 0.145). Cramer's V shows a strong correlation between all the categorical variables. Table 10 indicates that all variables have no association with the weekdays; hence, weekdays have no impact on fatal accidents. Furthermore, nationality does not impact the Type of accidents (X^2 = 16.989, p = 0.108), weekdays (X^2 = 3.007, p = 0.808), and the industry (X^2 = 25.700, p = 0.080). Adhikary et al.[21] found that workers' nationality and location have a strong association per this study's findings (X^2 = 26.182, p = 0.036). The nationality of workers recorded an association with workers' Activity (X^2 = 25.166, p = 0.033). Zerguine et al.[4] found an association between workers' nationality and their Activity.

Although this study acknowledges the fun and novelty of word clouds (or tag clouds) as a means of graphically representing text data, the authors maintain that these visual

representations can also be helpful evaluation tools. Word clouds provide investigators with a simple and rapid way to generate graphical representations of words reflecting the accident report. Textual patterns of words and phrases, or their absence, might help investigators pinpoint the root cause of an accident[10].

The most common three words in the description of the accident case died, fell, and victim. This indicates that falls from heights are the leading cause of occupational accidents in Malaysia and not just in construction, as reported by the authors[3][5][7][9]. As for the focus of the investigation, the most common words are procedure, fail, and work. This indicates the lack of safe operating procedures in the Malaysian workplace. Failure to perform a Hazard Identification, Risk Assessment, and Risk Control (HIRARC) as a mandatory risk assessment imposed by DOSH is another cause of occupational accidents in Malaysia. Supervise and provide are an indication that the management fails to supervise workers by providing a site safety supervisor and fails to provide the necessary training and personal protective equipment[9].

An Average score for the summary case of −0.632 indicates that most fatalities were severe, according to the reports of the site investigators. However, the score recorded by DOSH investigators is lower, with an average of −0.242. This can be due to the presence of the site investigator during the accident at the scene compared to DOSH investigators arriving a few days later.

Regarding individual sentiment score numbers, 487 accident cases scored an adverse sentiment which indicates a high severity with an average of −0.657, compared with five accident cases achieving a positive sentiment which suggests that the fatality was not that severe with an average of 0.127. Finally, 13 accident cases received a score of 0, which indicates a neutral sentiment toward the accident. As for the focus of the investigation, 347 accident cases scored a negative sentiment with an average of −0.418, indicating that DOSH investigators found that the recorded fatalities were severe, whereas 60 DOSH investigators scored a neutral sentiment for the accident. Furthermore, 98 DOSH investigators scored a positive sentiment with an average of 0.231, which indicates that the fatality was not severe.

Bag-of-words (BoW) is the foundation for this feature set, which is responsible for assigning term Frequency Inverse-Document Frequency (TF-IDF) values to each word in the dataset (except for unique words). The resulting TF-IDF vectors are then employed as features in a classification system. This strategy is based on the observation that certain words have varying frequencies depending on whether they are used in positive or negative contexts.

The LightGBM strategy improves readability and comprehension of the choices that go into making predictions for each given data point by making the many partition criteria and the leaf values into which each data point falls readily available to the user (see Fig. 8).

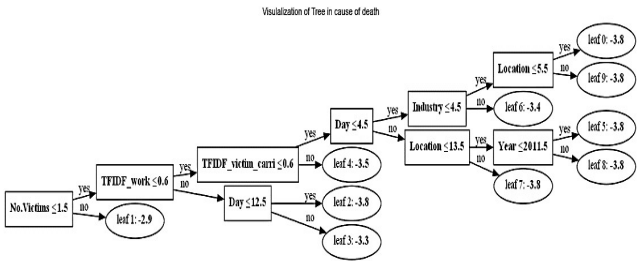

Fig. 8. Cause of death tree

6. Discussion

6.1 Injury Date and Workplace Fatalities A fifth of all accident cases recorded was in 2014 (n = 97, 19%), which is twice the average yearly accident number; there was a decline in the number of accidents after that, but then around 2018, it started going up again until 2020, which recorded 14% (n = 72, 14%) of all accident cases. 2014 high accident number could be due to the Gross Domestic Product (GDP) growth of the Malaysian economy in 2014 compared to previous years[22]. Malaysian employers are required to report work-related injuries to DOSH[2]; however, 2017 recorded (n = 23, 5%) accidents which was a meager average compared to others which indicates the efforts conducted by DOSH. DOSH procedures and regulations are comprehensive and inclusive of all safety management systems and are according to OHSAS 18001; however, fatal accidents remain a significant issue in the Malaysian workplace. Strict audits by DOSH are recommended to impose safety regulations on different workplaces. Regular training sessions and initiatives organized by DOSH can help spread safety awareness among decision-makers which may introduce a positive safety culture within the workplace.

6.2 Injury Month and Workplace Fatalities It is only a natural assumption since both months (October and November) are included in the Malaysian rainy season period, where extreme thunderstorms, rainy days, and occasional floods[23]. The high number of accidents can be attributed to unstable weather conditions. They work outside under the burning sun or the thunderstorms associated with Malaysia's tropical weather[24]. Fatima et al.[25] discussed in detail the association between extreme heat and work-related injuries, Malaysian weather is hot all year long, and heat strokes are standard among the locals. April recorded the lowest number of accidents (n = 30, 6%) in 10 years. April recorded the lowest number of accidents due to the stable weather conditions in Malaysia, which is the beginning of the dry season in Malaysia.

6.3 Injury Weekday and Workplace Fatalities Friday and Monday (n = 91, 18%) of the accidents recorded in 10 years amounted to 91. Amiri et al.[26] analysis found that accident numbers decreased during the last day of the business week, which contradicts the finding of this study. However, Amiri et al.[26] conducted their survey in Iranian workplaces, which may indicate different working traditions. On the other hand, both Amiri et al.[26]; and Shao et al.[17] uncovered the same outcome on Monday. Camino López et al.[27] suggested that accidents that happen on weekends may not be reported until Monday; the thought goes both ways. Whether employers will wait until the start of the week (Monday) to report the accident or the DOSH officers will not investigate the accident until Monday. Camino López et al.[27] named it the "Monday effect", where employers fail to report the accident until a working day for insurance purposes. The same can be said about DOSH employees using the Monday-

to-Friday system with two rest days. The same logic applies to Fridays; DOSH officers may have Friday as a deadline, where the accumulated accident reports will not be investigated until Friday.

6.4 Industries and Workplace Fatalities Due to the ever-changing nature of the construction industry and the large number of workers at the workplace at any point in time, it is challenging to create a standard prevention measure that can fit all; construction activities and practices vary from place to place[28]. Zid et al.[29] indicated that the construction sector is the highest contributor to the Malaysian economy but also the highest contributor to fatal accidents. Zid et al.[29] highlighted the strong correlation between the Malaysian construction sector and the Malaysian economy and how construction is one of the pillars Malaysia is counting on for the Malaysia 2030 development goal. Agriculture was the third highest-ranking sector of fatal accidents (n = 70, 14%), Abas et al.[30] uncovered that agriculture recorded more work-related injuries than construction and manufacturing. However, most accidents were not fatal but still caused permanent or non-permanent disabilities to the worker[1]. The rest of the industries recorded a significantly lower number of fatal accidents compared to the three sectors mentioned above; this might be due to the low-risk activities involved in these sectors[13]. Another factor to workplace accidents may be attributed to regional variations in levels of development, workforce caliber, the effectiveness of occupational safety and health laws, variety of job duties, and complexity of working conditions. They considered that the respondents in this study were all foreign workers and that 69% of the overall workforce in the construction industry in Malaysia is made up of foreign workers[31].

6.5 Injury Type and Workplace Fatalities Fatal falls from heights are the leading cause of fatal workplace accidents (n = 161, 32%) over ten years. These results were in line with findings from previous studies in different countries, such as Chi et al.[32] in Hong Kong, Dong et al.[33] in the United States, and Shao et al.[17] in China. Furthermore, Zermane et al.[9][10]; explored the contributing factors behind fatal falls from heights in the Malaysian construction industry and found that human and managerial factors were the leading causes behind these types of accidents. Struck came second after falls from heights with (n = 122, 24%) accidents[30]. highlighted the importance of struck-object accidents and concluded that 66% of all struck-by accidents could be avoided by promoting safety education and training. Various factors may cause employees to fail to report accidents. The thought that workers accept and feel that injuries are part of their profession because they occur regularly and are of low severity, or it may be due to the fear of losing their job or ruining their reputation, are some possible causes[4].

6.6 Injury Locations and Workplace Fatalities Johor recorded the highest number of accidents (n = 138, 27%) of all accidents; this could be due to the economic development in this state[34]. Abas et al.[35] study indicated a weak correlation between safety personnel perception and the recorded accident causes in the Johor area. The lack of safety awareness and perception among safety personnel points to a significant gap in safety knowledge and practices within Malaysian workplaces[35]. Vinodkumar and Bhasi[36] highlighted the importance of safety awareness within the company; safety motivation and training are critical in spreading positive safety culture. Zermane et al.[3] emphasized the size of the states where most accidents occurred; however, it may be applicable in some cases but not others. If you compare the size difference between Penang and Sarawak, Sarawak is 124 times larger than Penang[37]; However, when you compare by the number of inhabitants, both states have more than one million[37]. Nadhim et al.[38] indicated a correlation between workers' characteristics and fatal falls from heights; Individual elements included the lack of skills, knowledge, and training, misjudgment, and lack of experience. General workers' lack of technical skills and experience makes them susceptible to accidents that can prove fatal[9].

6.7 Activities and Workplace Fatalities General workers were the most affected by fatal accidents, followed by farmers and Drivers. According to Corrigan et al.[39], a safety culture within the company can significantly improve workers' morale and help prevent undesired events; however, this was not the case for the Malaysian workplace, where contract workers recorded higher accident numbers than self-employed workers. Furthermore, usually, contract workers are associated with large companies where the number of workers is far more significant than any self-employed workers. To help avoid future fatal accidents, it is advised that good communication, resource management, and supervision be carefully considered. It may be helpful to create a training and oversight certification program, encourage the clients of small projects to examine the contractors' compliance records and address these concerns specifically in small workplaces[40].

6.8 Employment Status and Workplace Fatalities Self-employed workers recorded (n = 181, 36%) all fatal accidents compared to contract workers. This high number is a reason for concern since self-employed workers are usually start-ups, Small and Medium Enterprises (SMEs), and family companies where the number of workers is less than in big companies. Compared to their wage-and-salary peers, who often get safety protection equipment from their employers, self-employed employees may have fewer resources to devote to safety instruction and equipment[33]. Moreover, organizational preventive measures were suggested, such as improving the organizational culture within these industries. The possibility of injury underreporting may rise since there are frequently no witnesses to offer details of the occurrence, and medical examiners may not effectively identify all work-related fatalities[33]. Despite the limitations, this study provides explicit support for the important initiatives by the Department of Occupational Safety and Health (DOSH) to prevent fatalities in Malaysia. Companies should have a written protection program that details what kind of safety equipment will be used for particular tasks. Moreover, ensure that workers receive adequate training on preventing fatal injuries and enforce safety management systems and safety standards applications throughout the organization. Furthermore, Improvements to design and engineering might also be made to remove risks, and multi-employer sites could adopt site-wide strategies to increase risk communication and significant modifications to tools and work methods[33].

Several preventative actions are advised, starting with the

development of training programs expressly for managers and supervisors of small contractors to enhance their abilities in safety management and supervision. Daily safety awareness exercises may be performed before starting work[40]. Furthermore, for specific forms of high-risk work, the industry may develop standard technical and managerial procedures; these procedures may then be promoted among small contractors, who typically lack strong technical and administrative skills[40].

The study's findings provide valuable insights that can inform targeted measures to enhance workplace safety across various industries in Malaysia. Based on the analysis of fatal workplace accidents. In the construction Industry, the study highlights the need for stringent safety protocols on construction sites, emphasizing measures to prevent falls from heights which constitute a significant portion of fatalities. Implementing comprehensive safety training and improving scaffolding standards are essential steps to reduce risks in this sector.

Concerning the manufacturing Sector, the findings emphasize the importance of enhancing machine safety through regular maintenance and engineering controls. Risk assessments and worker training on machinery operation and hazardous substance handling are critical to minimizing accidents in manufacturing. However, targeted awareness campaigns and safety training programs can empower general workers, who are identified as a vulnerable category, to recognize and report workplace hazards effectively. In addition, outreach programs aimed at educating self-employed farmers on agricultural safety practices, including safe equipment operation and livestock handling, are crucial to improving safety in informal agricultural settings. Moreover, policies should be developed to ensure the safety and welfare of contract workers, including comprehensive safety induction programs and collaboration with contracting agencies to prioritize worker safety.

Several measures across various sectors are imperative to enhance workplace safety. Increased frequency and depth of safety audits are crucial for general safety as they ensure compliance with existing regulations and identify areas lacking sufficient safety measures[41]. emphasize the effectiveness of third-party safety audits in preempting potential safety issues. Additionally, comprehensive training programs that are regularly updated to reflect the latest safety standards are vital[42]. highlight that these programs should be mandatory for all employees to maintain informed and safe practices. Furthermore, integrating modern technology, such as sensors and drones for site surveillance, enhances safety monitoring and quick response capabilities, as discussed by Chinander[43].

Specific interventions are also needed during periods with higher accident rates, such as February and October, particularly on Fridays and Mondays. In the present study, the authors suggest that targeted safety campaigns and stricter protocol enforcement during these times could significantly reduce accident peaks[44]. For high-risk industries like construction and manufacturing, specific measures are essential[45]. discuss the necessity of fall prevention systems in construction, while[46] recommend machine safety enhancements in manufacturing to prevent equipment-related accidents. For high-risk locations, regional safety initiatives tailored to specific needs, such as increased safety training and localized safety campaigns, are beneficial.

Addressing different types of accidents is also critical[47]. affirm that comprehensive fall protection programs can significantly reduce workplace accidents[48]. note that safety barriers and clear protocols can effectively mitigate struck-by and caught-in/between incidents. Additionally, regular electrical safety training and appropriate equipment grounding are essential for preventing electrocutions, and strict monitoring of flammable materials is necessary to prevent explosions.

Furthermore, tailoring safety approaches to specific worker categories can enhance workplace safety. Contract workers, given their higher vulnerability, need specific policies to ensure they receive the same training and protective measures as permanent employees, as suggested by the authors[49]. Similarly[50], authors advocate for specialized safety modules tailored to the unique risks.

The study underscores the need for allocating resources and inspections to high-risk industries like construction, while also developing industry-specific safety guidelines based on identified patterns of fatal accidents. Consequently, it is recommended to advocate for enhanced data collection by the national DOSH regulator to capture additional factors like worker demographics and root causes of accidents can facilitate more informed decision-making and targeted interventions.

7. Conclusion

This study analyzed 505 fatal workplace accidents across Malaysian states over a decade. providing insights into occupational safety challenges within various industries. The findings indicate notable peaks in fatal accidents during 2014 and 2020, which align with economic fluctuations likely influencing workplace activities and safety conditions.

The results revealed noticeable patterns related to Malaysian fatalities. To assess the true risk of fatal accidents accurately, it is considered that the rate of fatalities relative to the number of workers in each sector is often expressed as fatalities per 100,000 workers, which provides a more meaningful comparison of risk across industries. Without this context, the raw numbers of fatal accidents might not fully represent the relative safety or danger of different sectors.

The construction industry consistently recorded the highest fatality rates, emphasizing the need for enhanced sector-specific safety measures, mainly due to the high incidence of fatalities from falls. This highlights the risks associated with height-related activities and emphasizes the importance of effective fall-prevention strategies.

Fatal falls from heights recorded the highest number of fatal accidents, with almost a third of all fatalities. The statistical analysis revealed that fatal accidents were not uniformly distributed throughout the year, with February and October and Mondays and Fridays experiencing higher incidences. These patterns suggest that cyclical factors, potentially related to workflow changes, project deadlines, or seasonal weather conditions, significantly impact workplace safety.

Johor recorded the highest number of fatalities among

other states. General workers were the most vulnerable category (60%, n = 302) of all fatalities.

A significant finding from this study is the disproportionately high number of fatalities among contract workers compared to self-employed individuals, pointing to potential disparities in safety practices and protective measures across different employment statuses. This disparity highlights a systemic issue in the regulatory framework that requires urgent attention to ensure equitable safety training and resources for all workers.

The date of the accident has no impact on the number of victims; each casualty is a random event; however, the cause of death, location, and industry have a moderate association with the number of victims. Furthermore, the dates of accidents recorded a moderate association with the locations of the accidents and a weak association with other variables. Finally, the activity and industry recorded a strong correlation with each other and the employment status, nationality of workers, causes of death, and the location of the accident.

Furthermore, advanced statistical methods such as the Kruskal Wallis and Mann Whitney U tests allowed for a detailed examination of the interactions between factors such as industry, accident type, and worker demographics. The analysis provided evidence of significant associations between specific variables and the likelihood and severity of accidents, offering a basis for targeted interventions.

This study used data from the national DOSH regulator to understand fatality patterns in Malaysian workplaces which limits the scope of this study. On the other hand, this study used fatal accidents across ten years and covered all industry sectors. Furthermore, this data was collected from a reliable source representing the national authority responsible for enforcement and legislation related to DOHS.

By determining patterns of fatal accidents, fatal accidents can be effectively prevented. DOSH can focus on updating the standard working procedures for fatal accidents. General workers can be highlighted and selected as a vulnerable category, and some initiatives can be projected toward improving their awareness and overall working conditions. Most of the Agriculture fatalities were self-employed farmers; Self-regulation is a norm to be set by DOSH to help prevent accidents in agriculture. Construction is the most hazardous industry in Malaysia, with the highest fatalities; DOSH should focus several resources on regulating the construction industry[5][7].

In conclusion, the high rate of fatal workplace accidents documented in this paper calls for an integrated approach to enhance occupational safety, which includes stricter enforcement of safety regulations, the introduction of targeted preventive measures, and a comprehensive review of industry-specific practices. Future research should focus on longitudinal studies to monitor the effectiveness of safety interventions and to explore the socio-economic dynamics that contribute to the resilience or vulnerability of workers across different sectors. This approach would facilitate a deeper understanding of effective strategies to mitigate the risks faced by Malaysia's diverse workforce. Finally, more research and enhanced data collection should evaluate hazards for workers employed through temporary employment services.

References

(1) DOSH: "workplace fatal injuries rate in Malaysia.pdf", Malaysia Department of Occupational Safety and Health (2021) [Online]. Available: http://www.dosh.gov.my/index.php/en/national-occupational-accident-fatality-rate

(2) DOSH: "Guidelines on Safety and Health (Notification of Accident, Dangerous Occurrence, Occupational Poisoning and Occupational Disease) Regulations 2004 [NADOPOD]", Putrajaya (2004) [Online]. Available: https://www.dosh.gov.my/index.php/form-download/nadopod-1

(3) A. Zermane, M.Z.M. Tohir, and M.R. Baharudin: "Analysis of the Contributing Factors for Fatal Accidents due to Falls from Heights in Malaysia and the USA", p.22 (2020)

(4) H. Zerguine, S.B.M. Tamrin, and J. Jalaludin: "Prevalence, source and severity of work-related injuries among 'foreign' construction workers in a large Malaysian organisation: a cross-sectional study", *Ind. Health*, Vol.56, No.3, Art. No.3 (2018) doi: 10.2486/indhealth.2017-0205.

(5) A. Ayob, A.A. Shaari, M.F.M. Zaki, and M.A.C. Munaaim: "Fatal occupational injuries in the Malaysian construction sector–causes and accidental agents", *IOP Conf. Ser. Earth Environ. Sci.*, Vol.140, p.012095 (2018), doi: 10.1088/1755-1315/140/1/012095.

(6) H.Y. Chong and T.S. Low: "Accidents in Malaysian Construction Industry: Statistical Data and Court Cases", *Int. J. Occup. Saf. Ergon.*, Vol.20, No.3, Art. No.3 (2014) doi: 10. 1080/10803548.2014.11077064.

(7) A.R.A. Hamid, et al.: "Causes of fatal construction accidents in Malaysia", IOP Conf. Ser. Earth Environ. Sci., Vol.220, p.012044 (2019) doi: 10.1088/1755-1315/220/1/012044.

(8) M.Z. Mohammad and B.H.W. Hadikusumo: "A Model of Integrated Multilevel Safety Intervention Practices in Malaysian Construction Industry", Procedia Eng., Vol.171, pp.396–404 (2017) doi: 10.1016/j.proeng.2017.01.349.

(9) A. Zermane, M.Z. Mohd Tohir, M.R. Baharudin, and H.M. Yusoff: "Risk assessment of fatal accidents due to work at heights activities using fault tree analysis: Case study in Malaysia", Saf. Sci., Vol.151, p.105724 (2022) doi: 10.1016/j.ssci.2022.105724.

(10) A. Zermane, M.Z. Mohd Tohir, H. Zermane, M.R. Baharudin, and H.M. Yusoff: "Predicting fatal fall from heights accidents using random forest classification machine learning model", Saf. Sci., Vol.159, p.106023 (2023) doi: 10.1016/j.ssci.2022.106023.

(11) S.M. Zin and F. Ismail: "Employers' Behavioural Safety Compliance Factors toward Occupational, Safety and Health Improvement in the Construction Industry", Procedia—Soc. Behav. Sci., Vol.36, pp.742–751 (2012) doi: 10.1016/j.sbspro.2012.03.081.

(12) F. Ismail, N. Ahmad, N.A.I. Janipha, and R. Ismail: "Assessing the Behavioural Factors' of Safety Culture for the Malaysian Construction Companies", Procedia—Soc. Behav. Sci., Vol.36, pp.573–582 (2012) doi: 10.1016/j.sbspro.2012.03.063.

(13) N.H. Zakaria, N. Mansor, and Z. Abdullah: "Workplace Accident in Malaysia: Most Common Causes and Solutions", Vol.2, p.15 (2012)

(14) Y.D. Mohammed and M.B. Ishak: "A STUDY OF FATAL AND NON-FATAL ACCIDENTS IN CONSTRUCTION SECTOR", *Malays. J. Civ. Eng.*, Vol.25, No.1, Art. No.1 (2013)

(15) N.A. Rahman, M.S.M. Johari, and C. Dias: "Exploratory study on self-awareness and self-preparedness of Malaysian rail passengers for emergency evacuations", *Transp. Eng.*, Vol.7, p.100105 (2022) doi: 10.1016/j.treng.2022.100105.

(16) C.-F. Chi, T.-C. Chang, and H.-I. Ting: "Accident patterns and prevention measures for fatal occupational falls in the construction industry", *Appl. Ergon.*, Vol.36, No.4, Art. No.4 (2005) doi: 10.1016/j.apergo.2004.09.011.

(17) B. Shao, Z. Hu, Q. Liu, S. Chen, and W. He: "Fatal accident patterns of building construction activities in China", Saf. Sci., Vol.111, pp.253–263 (2019) doi: 10.1016/j.ssci.2018.07.019.

(18) N. Chintalapudi, G. Battineni, M.D. Canio, G.G. Sagaro, and F. Amenta: "Text mining with sentiment analysis on seafarers' medical documents", *Int. J. Inf. Manag. Data Insights*, Vol.1, No.1, p.100005 (2021) doi: 10.1016/j.jjimei.2020.100005.

(19) N. Agarwal and S. Das: "Interpretable Machine Learning Tools: A Survey", in 2020 IEEE Symposium Series on Computational Intelligence (SSCI), Canberra, ACT, Australia: IEEE, pp.1528–1534 (2020) doi: 10.1109/SSCI47803.2020.9308260.

(20) J.S. Bujang, M.H. Zakaria, and A. Arshad: "Distribution and significance of seagrass ecosystems in Malaysia", *Aquat. Ecosyst. Health Manag.*, Vol.9, No.2, pp.203–214 (2006) doi: 10.1080/14634980600705576.

(21) P. Adhikary, S. Keen, and E. van Teijlingen: "Workplace Accidents Among Nepali Male Workers in the Middle East and Malaysia: A Qualitative Study", *J. Immigr. Minor. Health*, Vol.21, pp.1115–1122 (2019) doi:

https://doi.org/10.1007/s10903-018-0801-y.
(22) I. Azer, H. Che Hamzah, S.A. Mohamad, and H. Abdullah: "Contribution of Economic Sectors to Malaysian GDP", Regional Conference on Science, Technology and Social Sciences (RCSTSS 2014), M.A. Abdullah, W.K. Yahya, N. Ramli, S.R. Mohamed, and B.E. Ahmad, Eds., Singapore: Springer Singapore, pp.183–189 (2016) doi: 10.1007/978-981-10-1458-1_17.
(23) Y.T. Tsang, I.W.H. Fung, V.W.Y. Tam, C.P. Sing, and C.T. Lu: "Development of an accident modelling in the Hong Kong construction industry", *Int. J. Constr. Manag.*, Vol.17, No.2, Art. No.2 (2017) doi: 10.1080/15623599.2016.1222664.
(24) B.M. Varghese: "Are workers at risk of occupational injuries due to heat exposure? A comprehensive literature review", Saf. Sci., p.13 (2018)
(25) S.H. Fatima, P. Rothmore, L.C. Giles, B.M. Varghese, and P. Bi: "Extreme heat and occupational injuries in different climate zones: A systematic review and meta-analysis of epidemiological evidence", *Environ. Int.*, Vol.148, p.106384 (2021) doi: 10.1016/j.envint.2021.106384.
(26) M. Amiri, A. Ardeshir, and M.H.F. Zarandi: "Risk-based Analysis of Construction Accidents in Iran During 2007–2011- Meta Analyze Study", Vol.43, p.16 (2014)
(27) M.A. Camino López, D.O. Ritzel, I. Fontaneda, and O.J. González Alcantara: "Construction industry accidents in Spain", *J. Safety Res.*, Vol.39, No.5, Art. No.5 (2008) doi: 10.1016/j.jsr.2008.07.006.
(28) H. Zerguine, J. Jalaludin, and S.B.M. Tamrin: "Behaviour Based Safety Approach And Factors Affecting Unsafe Behaviour in Construction Sector: A Review", Asia Pac. Environ. Occup. Health J., Vol.2, p.13 (2016)
(29) C. Zid, N. Kasim, A. Raza Soomro, and A. Laidoune: "The discrepancy in the construction industry of Malaysia: one of the most contributing industries in Malaysia's economy and the highest contributor of the fatal accidents", *IOP Conf. Ser. Mater. Sci. Eng.*, Vol.788, No.1, Art. No.1 (2020) doi: 10.1088/1757-899X/788/1/012034.
(30) A.B.L. Abas, D. Abd. R.B. Mohd Said, M.A.B. Aziz Mohammed, and N. Sathiakumar: "Fatal occupational injuries among non-governmental employees in Malaysia: Fatal Occupational Injuries in Malaysia", *Am. J. Ind. Med.*, Vol.56, No.1, Art. No.1 (2013) doi: 10.1002/ajim.22056.
(31) H. Zerguine, S.B.B.M. Tamrin, and J. Jalaludin: "D6-3 Evaluation of Safety Behavior and Work-related Injuries among Foreign Construction Workers in Malaysia", *Jpn. J. Ergon.*, Vol.53, No.Supplement2, Art. No. Supplement2 (2017) doi: 10/ggd83 g.
(32) C.-F. Chi, S.-Z. Lin, and R.S. Dewi: "Graphical fault tree analysis for fatal falls in the construction industry", *Accid. Anal. Prev.*, Vol.72, pp.359–369 (2014) doi: 10.1016/j.aap.2014.07.019.
(33) X.S. Dong, et al.: "Fatal falls in the U.S. residential construction industry: Fatal Falls in the U.S. Residential Construction Industry", *Am. J. Ind. Med.*, Vol.57, No.9, Art. No.9 (2014) doi: 10.1002/ajim.22341.
(34) S. Khanam and M.J.M.M. Noor: "A comparative static analysis of carbon tax policy and a Smart City-JB;, Johor Bahru, Malaysia", 2014 International Conference on Informatics, Electronics & Vision (ICIEV), Dhaka, Bangladesh: IEEE, pp.1–5 (2014) doi: 10.1109/ICIEV.2014.6850832.
(35) N.H. Abas, Y.W. Heong, H. Mohammad, S. Khalijah, and M.H. Rahmat: "The Analysis of Struck-By Accidents at Construction Sites in Johor", Vol.12, No.4, Art. No.4 (2020)
(36) M.N. Vinodkumar and M. Bhasi: "Safety management practices and safety behaviour: Assessing the mediating role of safety knowledge and motivation", *Accid. Anal. Prev.*, Vol.42, No.6, Art. No.6 (2010) doi: 10.1016/j.aap.2010.06.021.
(37) H. Booth, et al.: "Elasmobranch fishing and trade in Sarawak, Malaysia, with implications for management", *Aquat. Conserv. Mar. Freshw. Ecosyst.*, Vol.31, No.11, pp.3056–3071 (2021) doi: 10.1002/aqc.3688.
(38) E. Nadhim, C. Hon, B. Xia, I. Stewart, and D. Fang: "Falls from Height in the Construction Industry: A Critical Review of the Scientific Literature", *Int. J. Environ. Res. Public. Health*, Vol.13, No.7, Art. No.7 (2016) doi: 10.3390/ijerph13070638.
(39) S. Corrigan, A. Kay, M. Ryan, M.E. Ward, and B. Brazil: "Human factors and safety culture: Challenges and opportunities for the port environment", Saf. Sci. (2018) doi: 10.1016/j.ssci.2018.03.008.
(40) L. Wong, Y. Wang, T. Law, and C.T. Lo: "Association of Root Causes in Fatal Fall-from-Height Construction Accidents in Hong Kong", *J. Constr. Eng. Manag.*, Vol.142, No.7, Art. No.7 (2016) doi: 10.1061/(ASCE)CO.1943-7862.0001098.
(41) P. Hohnen and P. Hasle: "Third party audits of the psychosocial work environment in occupational health and safety management systems", Saf. Sci., Vol.109, pp.76–85 (2018) doi: 10.1016/j.ssci.2018.04.028.
(42) M.Z. Mohammad and B.H.W. Hadikusumo: "A Model of Integrated Multilevel Safety Intervention Practices in Malaysian Construction Industry", *Procedia Eng.*, Vol.171, pp.396–404 (2017) doi: 10.1016/j.proeng.2017.01.349.
(43) R. Kanan, O. Elhassan, and R. Bensalem: "An IoT-based autonomous system for workers' safety in construction sites with real-time alarming, monitoring, and positioning strategies", *Autom. Constr.*, Vol.88, pp.73–86 (2018) doi: 10.1016/j.autcon.2017.12.033.
(44) ANDREW HOPKINS: "Beyond Compliance Monitoring", *LAW POLICY*, Vol.29, No.2 (2007)
(45) A.R. Hale, F.W. Guldenmund, P.L.C.H. van Loenhout, and J.I.H. Oh: "Evaluating safety management and culture interventions to improve safety: Effective intervention strategies", Saf. Sci., Vol.48, No.8, pp.1026–1035 (2010) doi: 10.1016/j.ssci.2009.05.006.
(46) F. Gauthier, Y. Chinniah, D. Burlet-Vienney, B. Aucourt, and S. Larouche: "Risk assessment in safety of machinery: Impact of construction flaws in risk estimation parameters", Saf. Sci., Vol.109, pp.421–433 (2018) doi: 10.1016/j.ssci.2018.06.024.
(47) A. Zermane, M.Z.M. Tohir, M.R. Baharudin, and H. M. Yusoff: "Investigating patterns of workplace fatal fall injuries: Case study of Malaysia", *J. Safety Res.*, Vol.85, pp.492–506 (2023) doi: https://doi.org/10.1016/j.jsr.2023.05.003.
(48) D.P. Bui, et al.: "Interventions and controls to prevent emergency service vehicle incidents: A mixed methods review", *Accid. Anal. Prev.*, Vol.115, pp.189–201 (2018) doi: 10.1016/j.aap.2018.01.006.
(49) H.B. Başağa, B.A. Temel, M. Atasoy, and İ. Yıldırım: "A study on the effectiveness of occupational health and safety trainings of construction workers in Turkey", Saf. Sci., Vol.110, pp.344–354 (2018) doi: 10.1016/j.ssci.2018.09.002.
(50) V. Lugah, B. Ganesh, A. Darus, M. Retneswari, M.R. Rosnawati, and D. Sujatha: "Training of occupational safety and health: knowledge among healthcare professionals in Malaysia", *Singap. Med J*, Vol.51, No.7, p.6 (2010)

Hanane Zermane (Non-member) is currently a Professor in the Department of Industrial Engineering, University of Batna 2 (Algeria). Her research interests include Industrial Manufacturing, Automation, Process Control, Artificial Intelligence, and Knowledge Management.

Abderrahim Zermane (Non-member) is a Doctor of Philosophy, Department of Chemical and Environmental Engineering at Universiti Putra Malaysia. He is a member of the Safety Engineering Interest Group (SEIG) (Faculty of Engineering).

Mohd Zahirasri Mohd Tohir (Non-member) is currently on attachment at the Universidad de Navarra as an Investigator. Mohd Zahirasri does research in Forest Fire, Fire Risk Analysis, Probabilistic Analysis, Fire Safety Engineering and Safety Engineering.