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An Analysis of Fatal Construction Machinery Accidents in Türkiye between 2013 and 2018

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Keywords

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Abstract

Accidents involving construction machinery often result in injury and fatality. In this study, fatal work accidents involving construction machinery, which play an important role in the execution of work, in Türkiye between 2013 and 2018 are examined. The research utilized notifications made by workplaces to the Social Security Institution (SSI). The parameters used to statistically analyze the data were classified into three categories: accident time, the victim, and the cause of the accident. Based on the available data, the highest number of accidents occurred in 2017 with 23.03%, while September recorded the highest number of monthly accidents at 10%. Trucks were the most frequent construction machinery involved, accounting for 51.18% of all cases, and traffic accidents ranked first as the leading cause at 28.06%. This highlights the necessity of considering traffic accidents in workplace safety statistics and emphasizes the importance of traffic safety in ensuring occupational safety and health. Notably, truck accidents comprise more than half of all fatal incidents involving the 16 types of construction machinery analyzed.

Cite

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1. INTRODUCTION

The use of machinery in workplaces today provides significant time and labor savings. If the tasks performed by machinery were to be carried out by human labor, work losses and accidents would be much more frequent. According to Law No. 6331 on Occupational Safety and Health, published in the Official Gazette No. 28339 on 30.06.2012, a “work accident” is defined as an incident that occurs in the workplace or due to the execution of work, causing death or physical and mental disability. The use of inappropriate equipment, failure to maintain, repair, and inspect equipment on time, failure to take necessary precautions in the work environment, and workers' negligent behavior cause accidents in workplaces. In Türkiye, the Social Security Institution (SSI) collects data on work accidents. According to Article 14 of Law No. 6331 on Occupational Safety and Health, work accidents must be reported to the SSI by the employer within three working days following the accident (Occupational Safety and Health Law, 2012).

According to construction accident statistics published by the Construction Department of the Sectoral Risk Management and Statistics Directorate of the Directorate General of Occupational Health and Safety (DGOHS), based on SSI (2024) accident data, 64,184 insured workers in the construction sector in Türkiye experienced work accidents in 2022. Of these accidents, 422 people—27.8% of workers who died in work accidents in Türkiye in 2017—lost their lives. An examination of 2,578 fatal work accidents that occurred between 2013 and 2017 revealed that 44.4% of the accidents were due to falls from heights, 17.8% were due

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to traffic and machinery accidents, 6% were electrical accidents, and 5% were caused by equipment (DGOHS, 2019).

Gürcanlı et al. (2008) found that 42.9% of the 5,289 fatal and injury-causing accidents that occurred in construction areas in Türkiye between 1969 and 1999 were due to falls, 12.2% were due to contact with electricity, 10.5% were due to injuries from falling objects, 8.6% were due to machinery accidents, and 7.0% were caused by traffic accidents on-site.

In the United States, 5,250 fatal accidents were recorded in 2018, with transportation ranking first in all work-related fatalities with 2,080 accidents. Following transportation, the construction sector drew attention as the industry with the highest number of accidents. Drivers and truck drivers were the occupational group with the highest number of fatalities, with 966 fatal accidents. The highest data within this group was for heavy truck and trailer drivers, with 831 fatal accidents (BLS, 2023).

The Occupational Safety and Health Administration (OSHA) in the United States (OSHA, 2020) has categorized construction accidents into four main groups; falls, electrocution, being struck by or caught in/between objects and being struck by a vehicle.

Construction machinery is defined in the Highways Traffic Law No. 2918, published in the Official Gazette No. 18195 on 18.10.1983, as motor vehicles equipped with various equipment according to their work purpose and used in the work and services of institutions such as agriculture, industry, public works, and national defense. These vehicles are not used for transporting people, animals, or loads on highways. Some examples of construction machinery include asphalt plant machines, backhoe loaders, concrete pumps, concrete spraying machines, concrete batching machines, concrete mixers, bulldozers, pavers, graders, and personnel and load elevators. The required G-type license codes for construction machinery used on highways, including trucks, are expressed under code 105.15.

Sadeghpour and Teizer (2009) noted that many activities conducted on construction sites inherently carry risks, and due to the limited space in which construction machinery operates and the fast-paced nature of work, further complexities arise, as machinery may be constrained by materials, equipment, and temporary structures or buildings.

Ruff (2004) stated that blind spots in construction machinery pose significant risks and that in highway construction in the United States, 22 deaths occur annually due to risks associated with such construction machinery. Poor visibility, low light, and sudden movements are among the sources of risk. These risks increase particularly when vehicles are reversing or maneuvering in confined spaces. To reduce and eliminate these risks, sensor and camera systems, warning systems, signalers wearing appropriate personal protective equipment, and proper signage are used. Proper planning and operator training are also effective in reducing risks.

Hinze et al. (2005) noted that injuries resulting from being caught in or between objects are mostly caused by vehicle overturning or moving equipment parts.

Three main legal regulations exist for operator training in machinery. According to Article 11 of the Regulation on Safety and Health Requirements for the Use of Work Equipment (2013), published in the Official Gazette No. 28628 on April 25, 2013, the employer is required to ensure that workers responsible for using work equipment receive training on the risks that may arise from the use of this equipment and how to avoid them. If the equipment is to be used on the road, it will be subject to the Highways Traffic Law. According to Article 42 of this Law, "the training of machine operators and the certification of those who succeed in the exam will be provided by the Ministry of National Education or institutions authorized by the Ministry of National Education. The procedures and principles related to the operation of these institutions, as well as the training programs to be implemented, will be determined by the Ministry of National Education" (Highways Traffic Law, 1983). Finally, according to Article 5 of the Regulation on Vocational Training for Workers to Be Employed in Hazardous and Highly Hazardous Works (2013), published in the Official Gazette No. 28706 on July 13, 2013, it is mandatory for workers employed in jobs listed in the Annex-1 schedule to receive vocational

training before being hired. The use of construction machinery is particularly mentioned in the construction section of the Annex-1 schedule. Article 6(c) of the same regulation mandates the obtaining of an operator's certificate and driver's license issued by the Ministry of National Education or institutions authorized by the Ministry for the certification of the requirement specified in Article 5. It is important to regularly update the knowledge of machine operators and instill in them the habit of complying with precautions to reduce accidents. Operators should know the capacities, limits, and operational capabilities of the machines they use.

When examining the studies in the literature, it is observed that data related to the number of accidents in sectoral statistics are utilized. No direct study on accidents caused by construction machinery has been identified in Türkiye, but it has been mentioned in studies focusing on work accidents in the construction sector. This study examines accidents caused by machinery between 2013 and 2018 in Türkiye in detail, focusing on the time of the accident, the victim affected by the accident, and the cause of the accident.

2. MATERIAL AND METHOD

2.1. Data Collection and Evaluation

A system for reporting accidents that occur in the course of work is used by employers, and the accident reporting form of the SSI has been standardized according to the European Statistics on Accidents at Work (ESAW) methodology and published under code SSI-032 on the SSI website (Work Accident Occupational Disease E-Notification, 2023). Accordingly, when an accident occurs, the employer must report information about the workplace as well as the insured person's date of birth, nationality, gender, employment date, employment status, whether they have received vocational and occupational safety and health training, the activity they were performing at the time of the accident, the equipment/tool they were using, the event causing the injury, the type of injury, the cause of the accident, and the equipment/tool causing the accident. The accident data collected is published annually on the website of the SSI (Social Security Institution). These accidents are classified according to the codes of the classification of economic activities (NACE), the number of days of incapacity for work, gender, provinces, type of insurance, and the event causing the injury. Furthermore, accident frequency and severity rates are also presented. Within the scope of this study, data reported to the SSI between 2013 and 2018 was obtained from the Occupational Safety and Health Information Management System, and document analysis, one of the qualitative research methods, was used. In this context, the data related to accidents involving construction machinery was separated and classified according to the type of construction machinery. The classified data was evaluated using the SPSS 26 statistical package program. After obtaining the classification, descriptive statistical techniques were used to analyze the dataset in detail. Descriptive statistics were determined according to the parameters specified in the ESAW methodology. The ESAW methodology adopts an approach that facilitates categorization when analyzing accidents and aims to provide comparable data across European Union countries (Eurostat, 2012). Descriptive statistics are important as they provide summary information about the sample and observations made. In this study, univariate frequency analysis was used to better understand and interpret the dataset. Ethical standards for research and publication were adhered to in this study.

2.2. Variables

The data categories included in the ESAW methodology were considered as the main variables in this study. These are: the day, month, year, and time of the accident; the age, gender, marital status, and educational background of the insured affected by the accident; whether they had received occupational safety and health and vocational training; the construction machinery that caused the accident; the event that caused the accident; the event that caused the injury; and a description of the accident site. The parameters related to the timing of the accident are presented in Table 1.

To describe the demographic characteristics of workers who lost their lives in construction machinery-related work accidents, six parameters were used to obtain descriptive statistics regarding the victims. These parameters include educational background, occupational safety and health training, vocational training, gender, marital status, and age. The educational background was categorized into eight subcategories: illiterate, literate, primary school, middle school, high school, vocational school (associate degree), university

(bachelor's degree), and postgraduate. Age ranges were classified into five subcategories. The details of these parameters are presented in Table 2.

Table 1. *Parameters and Subcategories Related to the Timing of Accidents*

Variable	Subcategory
Accident Year	2018, 2017, 2016, 2015, 2014, 2013
Accident Month	January, February, March, April, May, June, July, August, September, October, November, December
Accident Day	Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday
Accident Time	00:01-07:59, 08:00-11:59, 12:00-15:59, 16:00-19:59, 20:00-00:00

Table 2. *Parameters Related to the Victims and Subcategories*

Variable	Subcategory
Educational Background	Illiterate, Literate, Primary School, Middle School, High School, Vocational School (Associate Degree), University (Bachelor's Degree), Postgraduate
OSH Training	Yes, No
Vocational Training	Yes, No
Gender	Female, Male
Marital Status	Single, Married, Divorced, Unknown
Age	15-24, 25-32, 33-40, 41-50, 51+

The parameters regarding the work equipment involved in the accident, the event causing the accident, the event leading to injury, and the location of the accident are shown in Table 3. The event causing injury and the accident location were used in alignment with ESAW (European Statistics on Accidents at Work) definitions. The categorization of equipment and the events causing accidents was carried out by two Occupational Safety and Health Experts with over 10 years of experience.

Table 3. *Accident-Related Parameters*

Variable	Subcategory
Equipment	Water tanker, Asphalt equipment, Concrete mixer, Concrete pump, Pipe layer, Tractor-trailer, Garbage truck, Bulldozer, Excavator, Grader, Jumbo, Truck, Snow blower, Loader, Vacuum truck, Road marking machine
Event Causing Accident	Trapped-Crushed Under, Traffic accidents, Overturning, Impact from equipment parts, Falling into a ravine/ditch, Falling materials, Heart attack, Squeezed between equipment and a structure, Crushed while reversing, Electric shock
Mode of Injury	Contact with electrical voltage, temperature, hazardous substances, Contact with sharp, hard, or rough material, Crushing/squeezing, Hit by a moving object, Suffocation, burial, entrapment, Horizontal or vertical impact with a stationary object, Health issue (heart attack), Unknown, Other
Accident Location	Inside the workplace, Outside the workplace

3. RESULTS AND DISCUSSION

Between 2013 and 2018, 1358 fatal work accidents involving equipment classified as machinery occurred. Figure 1, 2, and 3 provide information regarding the year, month, and day the accidents took place. In Figure 1, the accident percentage represents the ratio of the number of machinery-related accidents in the given year to the total number of construction machinery accidents between 2013 and 2018. Accordingly, the highest number of accidents occurred in 2017, accounting for 23.03% of the total.

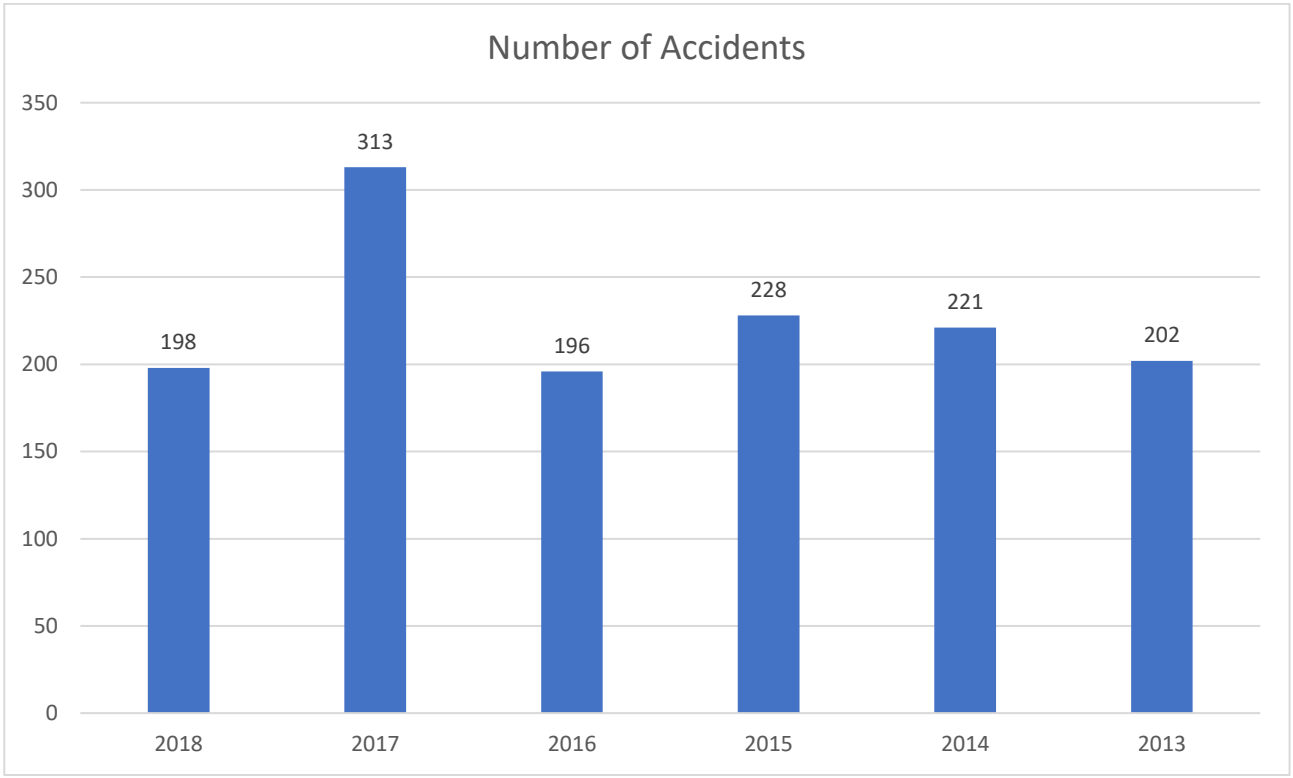

Figure 1. *Number of accidents by Year*

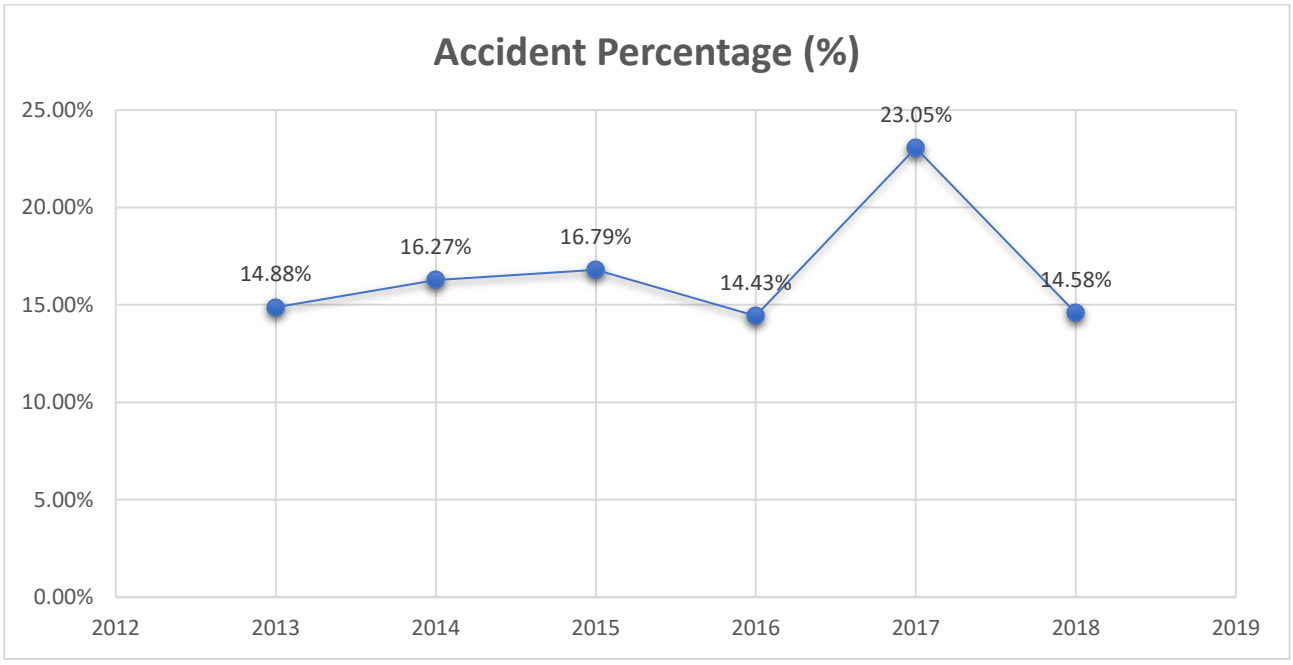

Figure 2. *Accident Percantages by Year*

Between 2013 and 2018, fatal accidents involving machinery most frequently occurred in September, July, and June. In Figure 3, the accident percentage represents the ratio of accidents in a particular month to the total number of accidents within the relevant time frame.

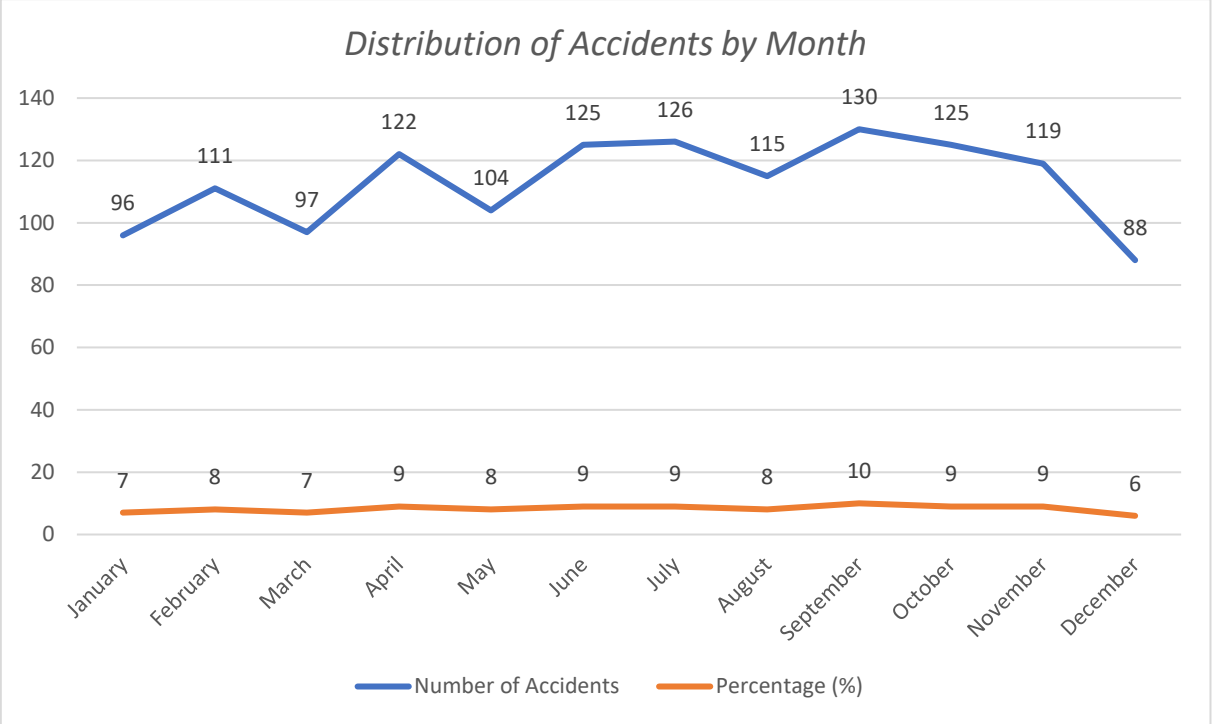

***Figure 3**. Distribution of Accidents by Month*

Figure 4 shows the percentage of accidents by day, indicating the proportion of accidents on a given day relative to the total number of accidents during the specified period. Fatal construction machinery accidents were most frequent on Monday (17.3%), followed by Wednesday (16.1%) and Tuesday (15.5%).

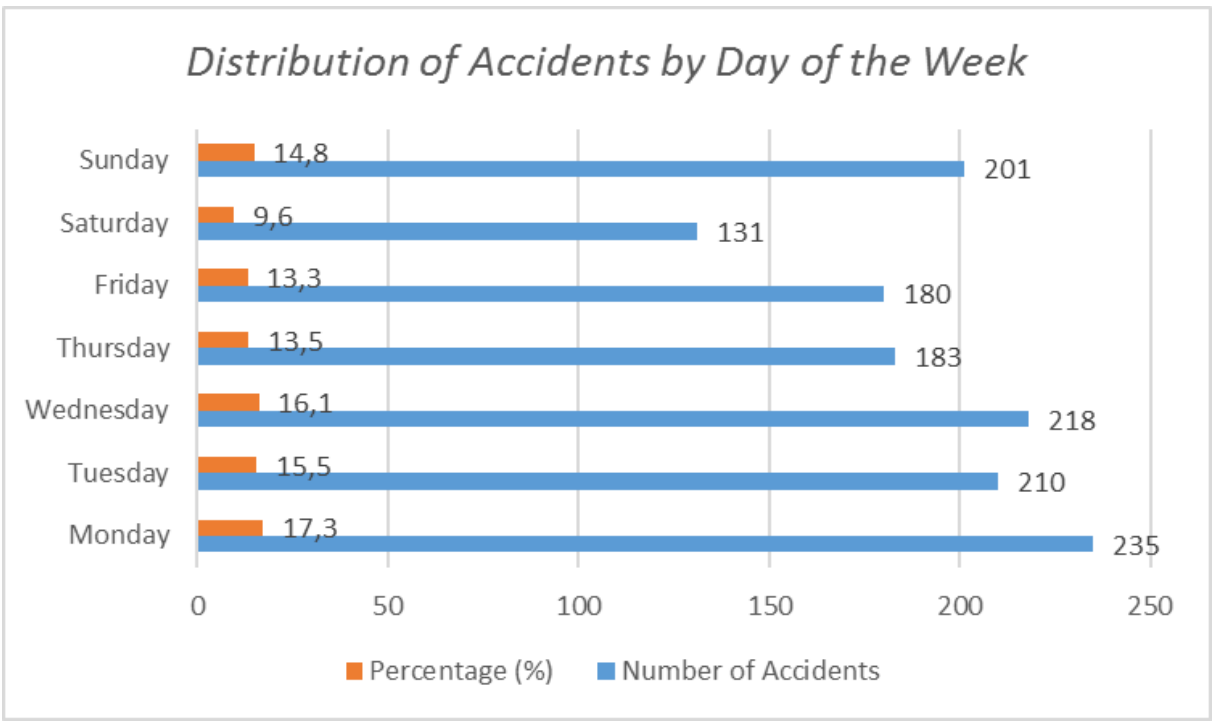

***Figure 4**. Distribution of Accidents by Day of the Week*

Between 2013 and 2018, fatal accidents involving construction machinery most commonly occurred between 08:00-11:59 (27.6%) and 12:00-15:59 (23.2%). The fewest accidents (10.3%) occurred between 20:00-00:00.

Workers aged 15-24, including young employees, constituted 6.1% of the victims, while this figure was 12.7% for the 25-32 age group, 18.3% for the 33-40 age group, 30% for the 41-50 age group, and 32.9% for workers over the age of 51.

Among the deceased workers, 13.9% were literate without formal education, 36.9% had completed primary school, 11.3% were graduates of elementary school, 18.4% had completed high school, and 1.1% held a university degree. Details are provided in Figure 5.

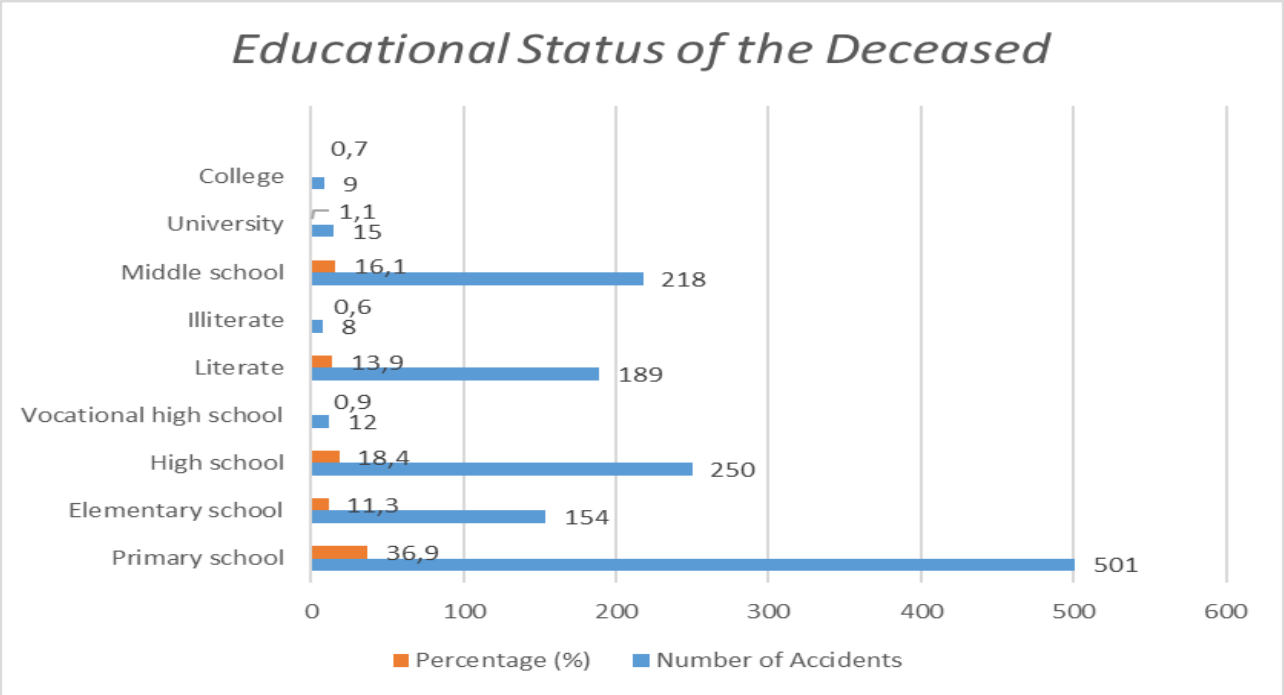

Figure 5*.Educational Status of the Deceased*

Among the deceased workers, 79.2% had received OSH training, while 81% had received vocational training. Of the accidents, 47.86% occurred outside the workplace, and 52.14% occurred within the workplace.

The equipment most frequently involved in fatal accidents included trucks (51.18%), tractors (22.46%), loaders (8.91%), and concrete mixers (3.76%). When fatal accidents involving construction machinery are analyzed by occupation, trucks and tractor + trailer/semi-trailer machines caused the most deaths among operators. Among those who died in tractor + trailer/semi-trailer accidents, 90.49% were operators, while 82.5% of those who died in truck accidents were operators. None of the workers who died in accidents involving jumbo machines, vacuum trucks, or road marking machines were operators. Details are provided in Table 4.

When examining the causes of accidents, it was found that traffic accidents accounted for 28.06% of all cases, making it the leading cause. As shown in Figure 6, other major causes of fatalities include overturning (15.83%), heart attack (13.62%), falling into a cliff/ditch (8.39%), and being crushed under machinery (7.36%).

Construction machinery, widely used in the construction industry, often differs in accident types due to their inherent nature compared to the more common accidents observed in the sector. While falls from heights, electrical hazards, moving machinery parts, and material falls are prominent causes of accidents in the industry, this study identifies traffic accidents, overturning, and heart attacks as the leading causes of fatal accidents (Winge & Albrechtsen, 2018).

Table 4. *Distribution of Accidents by Construction Machinery*

Equipment	Number of Accidents	Number of Operator Fatalities	Accident Percentage (%)
Water truck	3	2	0,22
Asphalt equipment (finisher, distributor, roller)	16	4	1,18
Concrete mixer	51	38	3,76
Concrete pump	43	9	3,17
Pipe layer	1	1	0,07
Tractor + trailer/semi-trailer	305	276	22,46
Garbage collection truck	45	11	3,31
Bulldozer	10	5	0,74
Excavator	44	23	3,24
Grader	17	9	1,25
Jumbo machine	3	0	0,22
Truck	695	574	51,18
Snow blower	1	1	0,07
Loader	121	46	8,91
Vacuum truck	2	0	0,15
Road marking machine	1	0	0,07

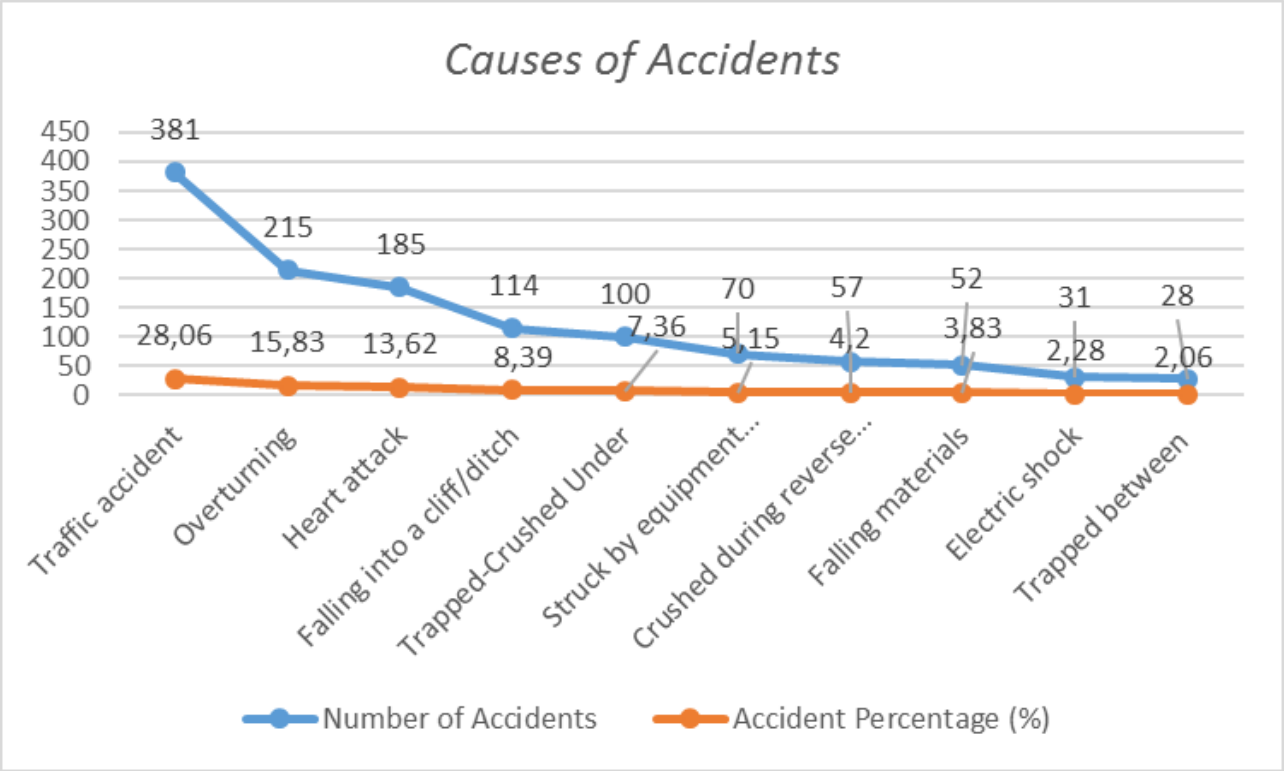

Figure 6. *Causes of Accidents*

The day with the highest frequency of fatal construction machinery accidents is Monday. This finding can be explained by the "Monday Effect" discussed by Card and McCall (1996), which suggests that employees tend to be less focused and engaged on the first day back at work.

In this study, the percentage of injured employees without occupational safety and health (O) training and vocational training was found to be 20.8% and 19%, respectively. Similar findings were reported by Hoła and Szóstak (2017) for construction accidents in Poland, where 20% of deceased employees lacked general OHS training and 25% had not received job-specific training. These figures underscore the importance of OHS training, vocational education, and on-the-job training in preventing work-related accidents.

Unlike the study by Gürcanlı et al. (2008), which focused specifically on the construction sector, this study includes all traffic accidents involving construction machinery. Gürcanlı's study was sector-specific, while this study aims to highlight the role of equipment in accidents and offer recommendations. The significant number of accidents involving trucks justifies this broader approach. However, it also brings to light the importance of traffic safety alongside occupational safety.

Yakar and Taçgın's study (2012-2016) identified the loader as the most frequently involved equipment in construction accidents, with a 36% share. This study finds that, similarly, trucks and tractors (which include traffic elements) rank highest in accident frequency, followed by loaders and concrete mixers (Yakar & Taçgın, 2019).

Hinze et al. (2005) observed that construction accidents were most frequent in March, April, summer months, and October. This study found that the highest number of fatal accidents occurred in September, with lower numbers in December and March. This pattern is likely related to the slower pace of construction activities during rainy or snowy weather.

Crushing accidents during reverse maneuvers are one of the most common causes of death in construction machinery accidents, apart from traffic accidents. The amendment added on February 18, 2022, to the Regulation on Health and Safety Conditions in the Use of Work Equipment (2013), mandates the use of object detection and warning systems in blind spots where workers can access, the use of markers in areas where such systems are not feasible, and ensuring that no one enters the equipment's operational area.

Teizer et al. (2010) integrated real-time fully automated warning devices for blind spots and pedestrian detection into construction equipment, and the application has been successfully used. Similarly, in the U.S., OSHA regulations (29 CFR 1926.601 and 602) require all trucks and mobile machinery to be equipped with reverse alarms (Kazan, 2013).

Yi et al. (2012) found that using correct color codes enhances visibility, helping older workers better distinguish objects and equipment. In cases where technical measures are inadequate, individuals in the working environment should wear high-visibility clothing (such as vests), and the area should be marked with appropriate colors. According to TS EN ISO 20471, the colors used for high-visibility clothing include fluorescent yellow, fluorescent orange-red, and fluorescent red (TSE, 2013).

4. CONCLUSION

This study examined 1,358 fatal accidents involving construction machinery across Türkiye from 2013 to 2018. The fact that truck accidents account for 51.18% and traffic accidents account for 28.06% of the total highlights the need for further scrutiny of traffic safety and the inclusion of traffic accidents in work accident assessments. The high frequency of accidents involving equipment such as loaders and concrete mixers also indicates the need for both technical and awareness-raising interventions.

Despite the publication of the Occupational safety and health Law in 2012 and the issuance of over thirty regulations, the sector has not yet achieved the desired reduction in work-related accidents. Thus, legislation alone or solutions based solely on field needs are not sufficient; these measures must be supported by safety culture and awareness-raising initiatives. The effectiveness of preventive measures is directly reflected in the reduction of accident numbers. For example, safety training and awareness programs can help workers identify

risks and implement preventive measures. Additionally, regular inspections based on industry or risk, and identifying potential hazards, will contribute to reducing accidents. In the study, the share of fatalities resulting from truck accidents is greater than that of all other equipment combined among the 16 types of construction machinery examined. Developing occupational health and safety policies for trucks has the potential to prevent many deaths, as they account for 51.18% of fatal construction machinery accidents. In this context, it is recommended to implement regulations specifically targeting the transportation, construction, mining, and agriculture sectors.

When examining the root causes of accidents involving trucks, they can be categorized as excessive speed and loss of control, fatigue, vehicle maintenance deficiencies, overloading, infrastructure issues and road conditions, and lack of driver training and experience. Focusing on all these causes and determining, implementing, and monitoring environmental, administrative, and technical measures will be a solution to prevent many fatalities.

AUTHOR CONTRIBUTIONS

In this article, the contributions of the authors are equal.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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