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Review Article

Investigation of Tower Crane Accidents in Türkiye between 2013 and 2017

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Abstract:

Booming construction sector requires extensive use of tower cranes. Lacking safety precautions may lead to severe tower crane accidents due to inherent risks. This study provides an in-depth overview of the construction sector, highlighting the significant risk of falling from height as a prevalent hazard and emphasizes the importance of vocational training for employees in the construction sector in Türkiye and presents global statistics on accidents in the construction industry, particularly focusing on tower crane accidents. Starting with worldwide tower crane accidents, their causes, hazards, installation procedures, and the impact of accidents on individuals this study also delves into the analysis of tower crane accidents in Türkiye between 2013-2017, examining various factors such as age, location of injuries, accident causes, and sector involvement. The study underscores the need for enhanced safety measures, training programs, and regulatory enforcement to mitigate accidents in works involving tower crane use.

In Türkiye, 1704 tower crane accidents were reported between 2013 and 2017. The distribution of these accidents by year shows an increasing trend from 2013 to 2017. Additionally, it highlights that 86% of all tower crane accidents occurred in the construction sector. The analysis also uncovers that there is a significant disparity among variables such as age, location of injuries on the body, accident causes, victims' occupations, and the province where the accidents occurred. However, no significant differences were observed among variables like accident time, experience, OSH training, professional education attainment, educational status, season of the accident, and day of the accident.

Key words: tower cranes; work accident; safety

Introduction

Construction Sector Overview

The construction sector continues its activities in response to the increasing population and evolving industrial needs. Various branches of construction industry encompass activities ranging from building construction to infrastructure projects such as bridges, tunnels, and metros, as well as repair and reinforcement works, underwater and above-water constructions.

Due to the inherent nature of the work, falling from height is considered the most significant risk factor in the construction sector (Gürcanlı and Müngen, 2013). In addition to falls from height, other risks include electric shock, falling objects or materials, and incidents involving being trapped under vehicles (ILO).

According to the Regulation on Occupational Safety and Health in Construction Works (2013) issued in Türkiye, working at height refers to tasks performed in areas with level differences and in locations prone to causing injuries due to falls, meanwhile this corresponds to 1.8 meters in Malaysia (Rafindadi et al., 2022).

Vocational Training in the Construction Sector in Türkiye

Employees in the sector, provided they perform the tasks listed in Annex-1, are obligated to undergo vocational training in accordance with Article 5 of the Regulation on the Vocational Training of Workers Engaged in

Hazardous and Very Hazardous Works (2013) and must substantiate this training with one of the documents specified in Article 6. Operators using equipment such as mobile cranes and tower cranes, included in Annex-1, must possess operator certificates issued by institutions authorized by the Ministry of National Education, as stipulated in Article 6 (c).

Those working in jobs requiring vocational training cannot start work without undergoing at least 2 hours of on-the-job training before using the work equipment, being assigned to their tasks, and without receiving practical training on the specific risks associated with the equipment, tasks, and work environment, as well as measures for protection against these risks.

Accidents in the Construction Sector Worldwide

In Malaysia, 38.16% (108) of the 282 reported construction sector accidents between 2010 and 2018 were related to falls (Rafindadi et al., 2022). According to OSHA data, in the United States, between 2002 and 2011, 3124 people lost their lives and 5210 suffered serious injuries in 9358 construction sector accidents. Of these accidents, 4110 were falls from height or same-level falls, 2409 were caused by object impacts or strikes, and 934 were due to being trapped (Chi and Han, 2013). In China, 9189 construction sector accidents occurred between 2004 and 2016, resulting in 1324 deaths in 2004, 624 deaths in 2011, and 734 deaths in 2016 (Zhang et al., 2019). In Europe, 782 fatal construction accidents were reported in 2013, with 26% due to falls from height, 20% due to material deterioration/falling/collapse, and 19% due to machine, equipment, or tool control loss (ESAW, 2013). In Korea, the most common accident causes in 2009 were reported as falls from height, caught in objects, same-level falls, struck by objects, and collisions (Kang and Kwon, 2011).

Cost of Accidents in the Construction Sector

A study conducted by Allison, Hon, and Xia (2019) in Australia, based on values from 2012 and 2013, determined that the ratio of direct costs to indirect costs for short-term job loss accidents was 8:13. For long-term job loss accidents, this ratio was 3:8, for accidents resulting in partial disability, it was 8:13, and for fatal accidents, it was 1:21.

Worldwide Tower Cranes Accidents

In the construction sector, various equipment such as facade scaffolding, tower cranes, mobile cranes, construction hoists, mast climbing working platforms, dump trucks and excavators are utilized according to the requirements of the job. Particularly in high-rise buildings, tower cranes are commonly employed due to their capacity and boom length, and incidents of work accidents may occur when necessary safety precautions are not implemented.

During a study on tower crane accidents conducted by Swuste between 2008 and 2009, it was indicated that load imbalance was the most common cause of crane accidents. A detailed technical investigation into the accident that occurred in Rotterdam on July 10, 2008 revealed that the tower crane selection was inappropriate, and necessary checks related to design were not conducted (Swuste, 2013).

In the United States, between 1992 and 2006, 632 workers lost their lives in 611 fatal crane accidents (U.S. Bureau of Labor Statistics, 2008). In Korea, 2100 crane-related accidents are reported annually, with 23.7% of these occurring on construction sites. Cranes rank fourth in equipment related accidents in construction, following temporary structures (scaffolding, etc.), construction equipment (excavators, loaders, etc.), and construction vehicles (Shin, 2014).

Beavers and Moore (2006) reported that, between 1997 and 2003, out of 119 fatal crane accidents reported to the Occupational Safety and Health Administration (OSHA) in the United States, only 12 of the deceased were crane operators. The remaining 107 were individuals performing other tasks such as riggers, laborers, carpenters, etc.

Tower Crane

General Terms

The concepts of winch and crane are sometimes confused. Technically, the terms "winch" and "crane" represent different aspects. In the TS EN 14492-1-A1 standard, a winch is defined as a machine designed to lift or lower loads suspended on hooks or other load lifting devices, transport loads on inclined surfaces (pulling or lowering), or pull loads in a special way on flat surfaces (TS EN 14492, 2010).

In the TS ISO 4306-1 standard, a crane is defined as a machine designed for lifting and transporting a load suspended by a hook or other load-bearing device, repeatedly operated, and for tower cranes, it is specifically defined as a rotating jib crane placed on top of a vertical tower (TS EN 4306, 2009).

The Turkish Science Terms Dictionary (TÜBA) defines a tower crane as a type of crane, usually used in construction, consisting of a cage-structured tower with a horizontally positioned load lifting part, based on the principle of balancing the load like a concrete block, and having lifting equipment that can be stationary or movable; synonym: construction crane.

Education and Awareness

The TS ISO 9926-1 standard specifies that crane operators should not have issues related to vision, hearing, or working at height, such as vertigo, and should not be substance-dependent (TS ISO 9926-1, 1997). In the Ministry of National Education's Directive on Driver Training Courses for Construction Equipment (2018), the term "having no condition that prevents operating" is used as a health requirement, and health reports obtained from relevant health institutions are utilized in this context.

Tam and Fung (2011) mentioned that in Hong Kong, the subcontracting system is widely used, where the main contractor outsources the provision of tower cranes to a subcontractor, and the subcontractor, in turn, sources tower crane operators from external sources. Due to subcontracting conditions, high labor mobility leads to insufficient training and site control, resulting in low employee loyalty and consequently higher accident rates.

Sertyeşilışık (2010) conducted research in the United Kingdom on lifting operations from the planning stages, concluding that crane teams need to enhance their experience and knowledge. Additionally, he determined that training on maintenance and inspection requires close monitoring.

Tower Crane Installation

According to the Regulation on Health and Safety Conditions in the Use of Work Equipment, Article 5 (2013), appropriate equipment must be selected for the job. When choosing a suitable tower crane, factors such as lifting capacity and space adequacy should be considered. Once the components of the tower crane are brought to the construction site, the first part of the cage is fixed with a concrete slab. The remaining parts are gradually assembled using a mobile crane. Subsequently, after the installation of the operator's cabin, tower head, jib, counter jib, and hook block, the interlocking process is completed (Shin, 2014).

According to Article 7-(1)-a) of the aforementioned Regulation (2013), tower cranes are subject to periodic inspections by authorized individuals defined in the Regulation, considering any changes made after each elevation or modification.

Tower Crane Hazards

The TS EN 14439+A2 standard is focused on the safety of tower cranes and is a Type-C standard based on equipment. Therefore, its provisions take precedence in cases of conflict with Type-A or Type-B standards. Since this standard is specific to tower cranes, its provisions do not apply to other cranes, such as loader cranes or mobile cranes. The hazards list of the standard includes significant risks such as crushing, shearing, impact, contact with live parts, neglecting ergonomic principles, malfunctioning of the control system, failure of the control circuit, access to the working area, inappropriate seating, inadequate evacuation in emergencies, inappropriate design and placement of controls, and inadequate design (TS EN 14439, 2010).

Shin (2014) lists hazards in tower crane installation as asymmetric loads due to improper foundation connections, improper installation of the telescopic shoe (incomplete fixation), weak connection of blocks to the mast, non-use of harnesses, and working without scaffolding or work platforms. Additionally, hazards during dismantling include unsafe dismantling of telescopic supports, inappropriate selection of the boom lifting position, rope breakage during dismantling, and imbalance due to not using the balance mast.

In their study, Zhou et al. (2018) created a list of 61 factors affecting tower crane safety through a literature review. This list was updated based on interviews with experienced engineers from China's top 10 leasing companies, and after a competency test at Huazhong University involving 113 construction managers, a final list of 56 factors was established. Results were analyzed using the AcciMap model, examining regulatory bodies (4 factors), crane stakeholders (manufacturers and contractors) (5 factors), construction site management (14 factors), field personnel (17 factors), and equipment with environmental impacts (16 factors). Nine fundamental dimensions of the tower crane safety system were identified through principal component analysis, including tower crane equipment quality and reliability, tower crane safety management and maintenance, tower crane safety program, employee safety practices, working environment, working conditions for tower crane use, inspector safety practices, auxiliary safety equipment, and government safety oversight.

Kim (2013), in his research on tower crane operators, found that workers faced more difficulties regarding climate, psychological, and physiological conditions when working on multi-story buildings compared to normal buildings.

Tower Crane Accidents

In Korea, tower cranes with a lifting capacity of more than 3 tons are required to be registered as construction equipment (Ministry of Land, Marine and Transportation, 2012). As of 2008, there were 3133 registered T-type and 276 L-type tower cranes, accounting for 7.2% of all lifting equipment accidents (Shin, 2014). According to the Occupational Health and Safety Standard updated in 2005, employers must prepare a safe installation and dismantling plan for tower cranes, and employees must comply with these plans (Ministry of Employment and Labor, 2005).

Between 2001 and 2011, 38 fatal accidents involving tower cranes occurred in Korea. Of these accidents, 68.4% occurred during installation and dismantling, with 31.6% resulting from violations of work procedures, 23.7% from inadequate safety procedures, 10.5% from damage due to inadequate supervision, 7.9% from unsafe use of the tower crane, and 26.3% from other causes (Ministry of Employment and Labor, 2013).

In Hong Kong, between 1998 and 2005, there were 12 tower crane accidents resulting in 14 fatalities (Tam and Fung, 2011). The primary causes of these accidents were identified as falling from height, impact of moving objects, impact of falling objects, and crushed under collapsing objects. Falling objects resulted in six deaths and were identified as the predominant cause.

In the detailed examination of the tower crane accident in Rotterdam in 2008, it was noted that despite deficiencies in the equipment during the production phase, the crane, which did not undergo additional checks due to obtaining the CE mark, was involved in the accident (Swuste, 2013).

Objective and Method

In Türkiye, work accidents must be reported to the Social Security Institution (SSI) within 3 working days by e-declaration administrators in accordance with the Occupational Safety and Health Act (2012). Data on work accidents reported through the system prepared according to the European Statistics on Accidents at Work (ESAW) methodology is maintained by the SSI and published annually. Data obtained from the Social Security Institution was classified in this study, considering all accidents reported between 2013 and 2017, and described as tower crane (winch) in the accident descriptions. In this study:

The accident data cover 1704 tower crane accidents that occurred in 81 provinces of Türkiye between January 1, 2013, and December 31, 2017.

In this study, descriptive statistical techniques were employed to comprehensively examine the dataset. These techniques are crucial for understanding the characteristics of variables in the dataset, gaining insights into the overall structure, and identifying potential relationships. Descriptive statistics provide summary information about the sample and the observations made. Univariate frequency analysis and cross-tabulation analysis represent two types of descriptive statistics.

Univariate analysis is generally the first analysis used by researchers who perform statistical analysis on various databases in different fields. The same can be said for studies in the field of occupational safety (Kazan, 2013). In this study, univariate frequency analysis was used to better understand the database and determine which information was available for cross-tabulation analysis. Also, univariate frequency analysis was used in the classification of variable categories. The results obtained in these analyses were examined through frequency tables.

After applying univariate analysis to investigate whether there is a significant relationship between pairs of independent variables, cross-tabulation analysis (binary analyses) was conducted. Cross-tabulation is a tabulation form with a matrix structure where one categorical variable is represented in rows and another in columns. After constructing the cross-tabulation and presenting frequency distribution in cells, the second stage involves examining the relationship between variables. In this stage, the Pearson chi-square test is one of the tests that can be used to interpret this relationship successfully (Sims, 1999). The Pearson chi-square test is a statistical test used to determine if there is a relationship between two categorical variables (Elliott, 2007). The chi-square statistic measures the difference between observed and expected frequencies and evaluates whether these differences are random. If these differences are statistically significant, we can infer that there is a relationship between the two variables.

In this study, the outcome of tower crane accidents was categorized into two groups: death and injury. This dependent variable was evaluated in relation to categorical independent variables related to accident parameters, accident time, and factors related to the accident victim, using the chi-square test. Descriptive parameters and their values were further detailed in Table 1. All statistical analyses in this study were conducted using the IBM SPSS 26 statistical package program, and a significance level of $p<0.05$ was accepted.

Control Parameters	Parameter Values
Year	2013, 2014, 2015, 2016, 2017
Season	Spring, Summer, Autumn, Winter
Province	İstanbul, Ankara, İzmir, Bursa, Kocaeli, Other
Educational Level	No Schooling, Primary School, Middle School, High School, University
Occupational Safety and Health and Vocational Training	Yes(present), No(absent)
Injured-Equipment Relationship Level	Using equipment, Affected by the accident
Age of the Injured	18-29, 30-39, 40-49, +49
Location of the Injury on the Body	Head region, Upper extremity, Trunk, Lower extremity, Multiple regions affected

Table 1 Descriptive Parameters and Parameter Values

Main Text:

Findings and Discussion

General Information about the Construction Sector

In Türkiye, out of 17,332,991 insured employees in 2022, 1,808,486 individuals were employed in the construction sector. The numbers of insured individuals in the construction sector during the time period when tower crane accidents were examined, from 2013 to 2017, are indicated in Table 2.

Year	Number of Insured
2013	1.849.942
2014	1.875.929
2015	1.980.630
2016	1.887.939
2017	2.083.438

Table 2: Number of Insured in the Construction Sector by Year

Tower Crane Accident Statistics

Descriptive Statistics

Between the years 2013-2017, parameters related to tower crane accidents were classified and recorded under a total of 27 different parameters containing detailed information about the accidents. All parameters were individually examined within the scope of the study, and accident reports were submitted by workplace personnel. The summary accident report table containing these description details is presented in Table 3.

Date	Location	Accident Description
11.1.2017	İstanbul	While the personnel was working in the basket, he moved to enter the building upon seeing that the tower crane was operating. At that moment, the tower crane hit the material it picked up, causing the adjacent formwork material, playmout, to fall. The falling piece hit the worker's head, causing his death.
06.12.2016	Erzurum	After the tower crane took and unloaded the material, it turned empty. During this time, the mold holding apparatus detached and fell on the worker's head, resulting in death.
03.10.2015	İstanbul	The mold material attached to the tower crane, after rising approximately 5 meters from the ground, came off the tie and fell on the worker performing the load binding task.
04.03.2014	İstanbul	While the tower crane was moving freely, one of its stabilizing legs broke, causing the crane to tip over, and the victim was trapped under the crane.
07.07.2013	Erzincan	During work under the supervision of the signaler, when lifting a tie rod with the tower crane (despite incorrect connection in terms of rope, sling, chain, etc.), the connection points broke one after the other as the tie rod was lifted, resulting in the tie rod falling on the worker and causing his death.

Table 3: Accident Notification Screen Summary

Between the years 2013 and 2017, a total of 1704 tower crane accident reports were examined for 1627 insured individuals in the annual reports of the Social Security Institution (SGK). The distribution of these accidents by year reveals that in 2013, there were 259 cases (15.2%), in 2014, 218 cases (12.8%), in 2015, 341 cases (20%), in 2016, 415 cases

(24.4%), and in 2017, 471 cases (27.6%) of tower crane accidents as indicated in Figure 1.

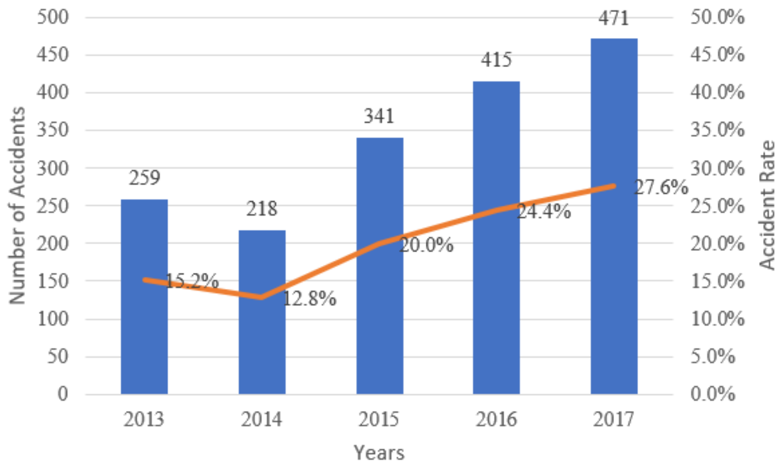

Figure 1: The Number of Tower Crane Accidents

During the specified period, 20.95% of all tower crane accidents occurred in winter, 28.29% in spring, 26.47% in summer, and 24.3% in autumn. Among the individuals involved in accidents, 34.1% were reported to be single, while 63.5% were married. It is noteworthy that 95.8% of the accident victims received occupational safety and health (OSH) training, and 84.9% had professional training.

As indicated in Table 4, only 4.2% of the accident victims did not receive OSH training, while this rate is 15.1% in terms of lacking vocational training. Considering the high rates, it can be observed that these training programs fall short in terms of awareness. In this context, a study conducted by Brahm and Singer, involving 2787 Chilean firms, found that doubling the content of safety training and making it more engaging led to a 3.7% reduction in accidents, and employing the most effective training method with the same content resulted in a 12.5% reduction (Brahm & Singer, 2013). More effective methods tailored to specific workplace risks should be applied in training programs. Similarly, Li (2012) suggests providing safety training using virtual reality during installation.

	Yes	No
Vocational Training	%84,9	%15,1
OSH Training	%95,8	%4,2

Table 4: Vocational and OHS Training Status of Accident Victims

A total of 27 accidents (1.6%) occurred between 00:00-05:59, 824 accidents (48.4%) between 06:00-11:59, 747 accidents (43.8%) between 12:00-17:59, and 106 accidents (6.2%) between 18:00-23:59.

Of the incidents, 985 (57.8%) occurred in Istanbul, 243 (14.3%) in Ankara, 62 (3.6%) in Izmir, 32 (1.9%) in Bursa, 44 (2.6%) in Kocaeli, and 338 (19.8%) in other cities. Thus, during the specified period in Türkiye, 80.2% of the tower crane accidents occurred in Istanbul, Ankara, Izmir, Bursa, and Kocaeli (Figure 2). In 10 cities, only one tower crane accident occurred during the specified date range.

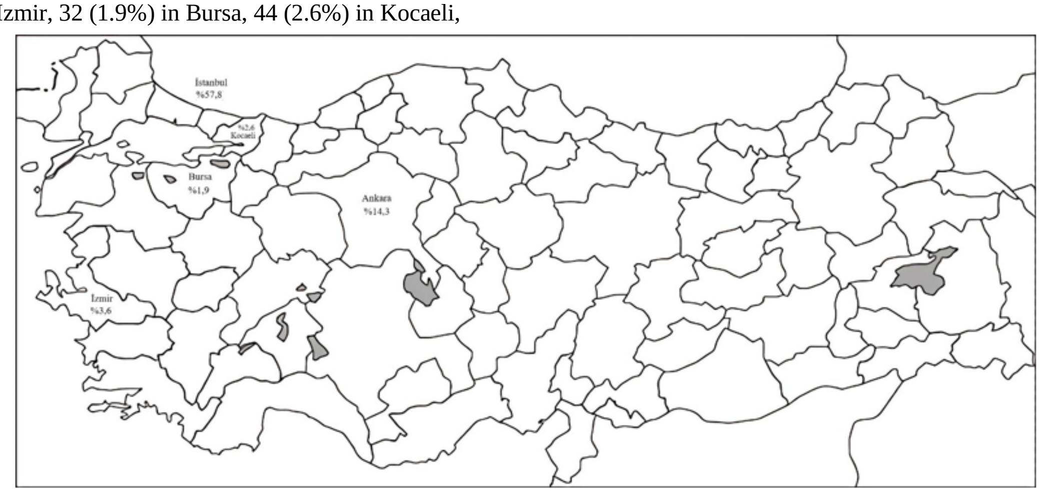

Figure 2: Distribution of Accidents by Provinces

The insured involved in accidents include 595 (34.9%) who completed primary school, 510 (29.9%) with middle school education, 276 (16.2%) with high school education, and 48 (2.8%) who graduated from university (Figure 3).

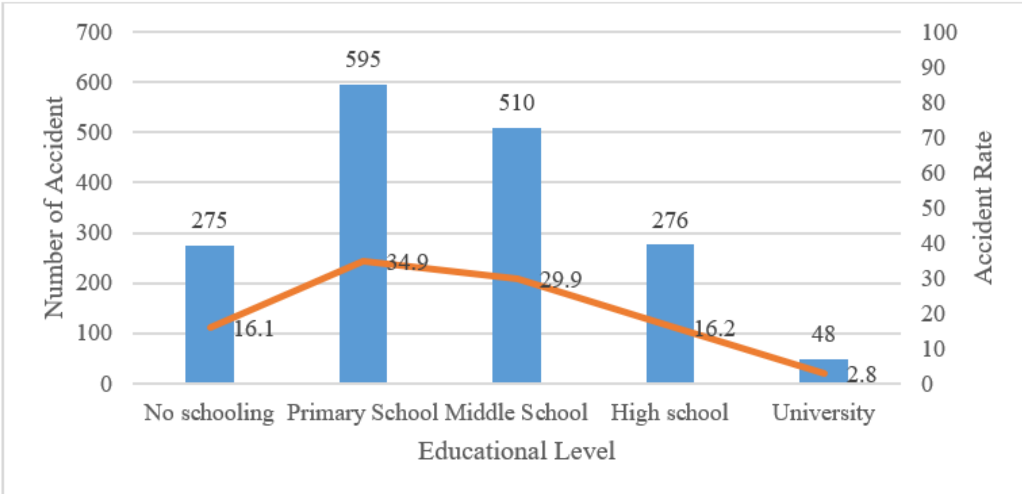

Figure 3: Educational Level of the Accident Victim

When examining the individuals affected by accidents based on their professions; 1412 insured are reported as other workers affected by accidents (82.9%), 123 insured as caregivers (7.2%), 69 insured as tower crane operators (4%), 52 insured as riggers (3.1%), and 48 insured (2.8%).

Relational Analyses

Tower crane accidents have occurred in all 81 provinces of the country. The results of the analysis on the impact of the province where the accident occurred on the accident outcome are presented in Table 5.

	PROVINCE								
	İstanbul	Ankara	İzmir	Bursa	Kocaeli	Other	χ2	SD	p.
Injury	974	242	59	32	44	326	17,336	5	,010
Death	11	1	3	0	0	12			
Total	985	243	62	32	44	338			

Table 5: Impact of the Province where the Accident Occurred on the Accident Outcome

The chi-square value for the table with 5 degrees of freedom between the accident outcome of death or injury and the province where the accident occurred is 17.365, indicating a significant difference ($p<0.05$). This association may be attributed to an increased incidence of tower crane accidents in areas characterized by industrialization and high population density. Tower crane accidents in Istanbul constitute 57.8% of all accidents, while fatal accidents in Istanbul account for 40.7% of all fatalities. The increase in tower crane accidents in areas with higher industrialization is observed in parallel with the increased use of tower cranes.

It should be noted that not only operators but also those involved in installation or dismantling, maintenance personnel, workers in the vicinity during loading and unloading, and even visitors can be affected in tower crane accidents. The results of the analysis examining the impact on operators and other individuals are provided in Table 6.

	OCCUPATION				
	Using the Equipment	Affected by the Accident	χ2	SD	p.
Injury	116	1561	5,422	1	,038
Death	5	22			

Table 6: Impact of Equipment Usage during Accidents on Accident Outcome

There is a significant difference between the occupation and the outcome of death and injury in accidents (p<0.05). The ones using the equipment (operator + rigger) were considered to be directly affected by the crane, while all other occupations except these two occupational groups were categorized as workers affected by the accident. A total of 22 different occupational records of accidents resulting from tower crane incidents were identified. Upon detailed examination of information pertaining to 1704 accident victims, the ratio of those directly involved with the equipment during the operation of the tower crane, i.e., operator + rigger, was determined to be 7.1%. Consistent with the studies of Beavers and Moore (2006), this result highlights the necessity of training riggers as well as tower crane operators and increasing awareness of the risks associated with tower crane use. Similarly, Tam and Fung (2011) have pointed out that crane operators often operate without a clear and unobstructed view of the load being moved, posing a problem for the workers below (riggers, signalers, etc.).

Table 7 shows that there is a significant relationship between the age of the accident victim and the outcome of the accident (p<0.05). The results draw attention to the fact that as the age of the accident victim increases, the occurrence of accidents decreases. In other words, tower crane accidents are both numerically and proportionally more frequent among younger workers. It can be argued that younger workers may lack sufficient experience compared to older workers and have lower levels of awareness.

AGE							
	18-29	30-39	40-49	+49	χ2	SD	p.
Injury	659	545	332	141	8,053	3	,042
Death	6	10	5	6			
Total	665	555	337	147			

Table 7: Impact of the Age of the Accident Victim on the Accident Outcome

As indicated in Table 8, there is a significant difference between the location of the injury on the body and the outcome of death and injury in accidents (p<0.05). In this context, 44.4% of fatal accidents result from injuries to the head, while fatal accidents are not observed in accidents involving the upper extremities, trunk, and lower extremities. Injuries to the head are identified as the second most affected region. Due to the nature of the work, accidents involving work at heights or material handling at heights often result in the head being particularly affected in falls involving the entire body and materials, leading to a higher incidence of fatalities originating from head injuries.

LOCATION OF THE INJURY ON THE BODY								
	Head Region	Upper Extremity	Trunk	Lower Extremity	Multiple Regions Affected in the Body	χ2	SD	p.
Injury	432	477	146	354	268	44,348	4	,000
Death	12	0	0	0	15			
Total	444	477	146	354	283			

Table 8: Impact of the Wound Region on the Accident Outcome

The heightened lethality associated with injuries to the head in accidents, particularly in the context of tower crane installation, operation, and dismantling activities that inherently necessitate elevated work, emphasizes the imperative of ensuring optimal access conditions. This entails prohibiting personnel transportation in the tower crane basket, and mandating the provision and proper utilization of personal protective equipment against falls from height.

There is a significant difference between the cause of the accident and the outcome of death or injury (p<0.05) (Table 9). The accident causes are classified according to the main headings of ESAW methodology. Among fatal accidents, the most common cause is individuals slipping, stumbling, or falling, accounting for 37%. For accidents resulting in injuries, the most prevalent cause is identified as external accidents, accounting for 38.9% outside of the eight main ESAW accident reasons. A study on crane accidents worldwide between 2011-2015 revealed that crane collapse constituted 38% of tower crane accidents, which is also identified as a significant cause in this study (Milazzo et al., 2017).

ACCIDENT CAUSE												
	Deviation due to electrical problems, explosion, fire	Deviation by over flow, overturn, leak, flow, vaporisation, emission	Breakage, bursting, splitting, slipping, fall, collapse of Material Agent	Loss of control (total or partial) of machine, means of transport or handling equipment	Slipping - Stumbling and falling - Fall of persons	Body movement without any physical stress	Body movement under or with physical stress	Shock, fright, violence, aggression, threat, presence	Other	χ2	[illegible]	[illegible]
Injury	16	78	235	357	204	67	65	2	651			
Death	0	2	7	1	10	0	0	0	7	23,617	[illegible]	[illegible]
Total	16	80	242	358	214	67	65	2	658			

Table 9: Impact of the Accident Cause on the Accident Outcome

There is no significant difference between the season and the outcome of death or injury (p>0.05). The analysis examining the relationship between the sector where the accident occurred and the accident outcome is presented in Table 10.

SEASON							
	Winter	Spring	Summer	Fall	χ2	SD	p.
Injury	348	473	444	412	5,479	3	,107
Death	9	9	7	2			
Total	357	482	451	414			

Table 10: Impact of the Season in which the Accident Occurred on the Accident Outcome

A total of 11 different sectors were identified to have experienced tower crane accidents, and 86% of all accidents occurred in the construction sector. Therefore, accidents in the 10 sectors excluding construction were collectively considered under the 'other' category. An analysis was conducted to examine whether there is a significant difference between the occurrence of fatalities or injuries and the sector in which the tower crane accident occurred. The analysis results showed p>0.05, indicating that there is no significant difference between the sector and the accident outcome according to the obtained data (Table 11).

SECTOR						
	Other	Production	Construction	χ2	SD	p.
Injury	69	168	1440			
Death	1	1	25	1,219	2	,544
Total	70	169	1465			

Table 11: Impact of the Sector in which the Accident Occurred on the Accident Outcome

Shin (2014) asserts, in his investigation, that human error stands as the predominant cause of accidents during tower crane installation and dismantling, as reported by interviewed individuals. It is noteworthy that this study, conducted within the scope of the ESAW methodology, does not delve into the examination of the influence of the human factor on accidents based on reported incidents.

Conclusions:

The examination of tower crane accidents in Türkiye spanning the years 2013 to 2017 has provided insights into the incidents and their associated factors. Chi-square analyses revealed a significant disparity among the dependent variables, specifically the outcomes of death and injury, in relation to age, location of injuries on the body, accident causes, victims' occupations, and the province where the accidents occurred. However, no significant differences were observed among variables such as accident time ($p=0.0523$), experience ($p=0.331$), OSH training ($p=0.636$), professional education attainment ($p=0.626$), educational status ($p=0.505$), the season of the accident ($p=0.137$), and the day of the accident ($p=0.382$).

The analysis is constrained by the limitations of the existing dataset. Subsequent studies should undertake a more comprehensive examination of accident reports and other documents, following the acquisition of additional permissions. Moving beyond the constraints of the ESAW methodology, a thorough reevaluation of the causes of accidents is warranted. The ESAW methodology only allows for the identification of the primary visible cause, precluding an exploration of managerial issues and the impact of regulatory applicability and enforcement deficiencies on accidents.

Data availability statement:

Some or all data, models, or code generated or used during the study are proprietary or confidential in nature and may only be provided with restrictions. (All the data used in the study is confidential)

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