Research Report

of

Fatalities and Preventions in Residential Building Construction

Prepared for:
Job-Site Safety Institute (JSI)
P.O. Box 97503
Raleigh, NC 27624

c/o Rob Matuga, Executive Director of JSI

Prepared by:
Dong Zhao, Ph.D.
Associate Professor, Interim Construction Management Program Director

School of Planning, Design and Construction
& Human-Building Systems Lab
Michigan State University
552 W Circle Dr, East Lansing, MI 48824
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EXECUTIVE SUMMARY

The Job-Site Institute (JSI) commissioned this study intending to take a deep dive into existing information on fatalities within residential building construction to capture critical characteristics for job site injury prevention. This study, conducted by the Construction Management Program at Michigan State University, involved analyzing detailed, confidential fatality reports from 2014–2018 because the industry wanted to better understand the fatality incidents such as frequency, causes, and changes to reduce the risk of workers from injuries.

The study used data collected from the U.S. Department of Labor's Bureau of Labor Statistics' (BLS) including the Census of Fatal Occupational Injuries (CFOI), the Survey of Occupational Injuries and Illnesses (SOII), and the Current Employment Statistics (CES) program. Some of the CFOI data were confidential and restricted with access under a data agreement from BLS. A total of 5,003 fatal work injuries in construction were included, of which 603 were from the residential building construction sector.

Multiple analytical approaches were applied to provide a comprehensive understanding of the information from the national datasets. The analytical approaches included factor analysis, longitudinal analysis, comparative analysis, and ergonomic analysis. These analyses aimed to characterize the fatal work incidents in residential construction, capture the changes and trends over time, benchmark across construction sectors, and recommend prevention strategies. The data analyses presented a system thinking to highlight the interactions among various factors and aspects because no fatal injuries should be a result of a single factor.

Key findings include:

- The fatality rate in residential construction was 10.9 deaths per 100,000 full-time equivalent workers, 11% higher than the average fatality rate of all construction sectors.
- The number of fatalities in residential construction continued to grow after the year 2011.
- The fatalities increased in the spring and summer months until reaching a peak in August (12%), and decreased in the fall and winter months with a bottom in December (6%).
- Almost 88% of all deaths occurred on workdays from Monday to Friday, with a short peak on Monday (21%) and similar totals on each of the other days.
- Over half of fatalities occurred between 10 a.m. and 3 p.m. (61%), with the peak around 1 p.m. and 3 p.m.
- More than one-third of fatalities occurred in the South region[1] (35%). The region also had the largest portion of construction employment.
- Home-related construction sites experienced the highest number of fatalities (76%).
- Construction laborers (40%), carpenters (22%), and first-line supervisors (21%) were the top high-risk occupations in fatal work incidents.
- Most victims were white (77%) and multiracial (13%). Hispanic workers accounted for 27% of fatalities. Only 18% of the white victims were Hispanic.

[1] DC, MD, VA, DE, WV, NC, SC, KY, TN, GA, FL, AL, MS, AR, OR, LA, and TX.

- Nearly all victims were male by gender. There were 2 female victims in total.
- Workers 45-64 years of age accounted for almost half of the fatalities: the age groups of 45-54 years (25%), and 55-64 years (24%).
- More than half of fatalities were due to falls from height (52%). Most of the fatal falls were from ladders, roofs, and scaffolds and peaked at a height of 11–15 feet (16%).
- Exposures to harmful substances, especially the use of drugs and alcohol, became a **new** major cause of death (16%), followed by transportation accidents (12%).
- Constructing activities (55%) were dominant in fatal work incidents, such as building, repairing, cleaning, assembling, installing, and painting, followed by vehicular and transportation operations (14%).
- Head remained the most vulnerable part of the body in the fatal incidents (37%). The nature of most injuries was intracranial injuries, namely traumatic injuries to the cranium or skull and the structures within.
- Small-sized establishments with 10 or fewer employees were the core in the fatal work incidents (87%).
- Most victims were employed by wage and salary (63%) and self-employed (35%).

Overall, most characteristics in the residential building construction sector were stable compared to other construction sectors. The notable changes in worker activity, event and exposure, source of injury, and nature of injury together suggested a trend of increasing drug and alcohol use as an emerging cause of death in residential construction.

INTRODUCTION

Residential building construction is a major contributor to the U.S. economy. According to the U.S. Census Bureau, the residential sector contributed a total of $825.9 billion value which accounted for 50.2% of the overall business value created by the whole construction industry in 2021. Home builders and residential specialty trade contractors hired 3.1 million employees by 2021. Based on the 2017 U.S. Economic Census, the residential building construction sector had 171,814 establishments, 63.7% of which were small sized with fewer than ten employees, and provided $372.8 billion in annual payroll.

METHODS

Data

The fatality data used in this report are from the U.S. Bureau of Labor Statistics (BLS). The BLS's Injuries, Illnesses, and Fatalities (IIF) program provides annual information on the rate and number of work-related injuries, illnesses, and fatal injuries, and how these statistics vary by incident, industry, geography, occupation, and other characteristics. These data are collected through the Census of Fatal Occupational Injuries (CFOI) and the Survey of Occupational Injuries and Illnesses (SOII).

The definitions of industry and sectors are based on the standard of the North American Industry Classification System (NAICS) which is used by federal statistical agencies to classify business establishments [1]. The specific NAICS codes used in this study are listed below:

- NAICS 2361 - Residential Building Construction
- NAICS 2362 - Nonresidential Building Construction
- NAICS 237 - Heavy and Civil Engineering Construction
- NAICS 238 - Specialty Trade Contractors

The fatality data used in data analysis include an overall 5,003 fatal injuries in all construction sectors, including 603 deaths in residential building construction (NAICS 2361). The data range is the five years from 2014 to 2018. The fatality distribution by year is as follows:

- 2014: 933 cases (107 residential cases)
- 2015: 985 cases (107 residential cases)
- 2016: 1,034 cases (128 residential cases)
- 2017: 1,013 cases (135 residential cases)
- 2018: 1,038 cases (126 residential cases)

The data on worker employment, establishments, work hours, and payroll are collected from the BLS Current Employment Statistics (CES) program and other national economic census databases. The CES data offer detailed industry estimates of nonfarm employment, hours, and earnings of workers on payrolls. The employment data used for rate calculations are based on the number of workers rather than hours of work, or full-time equivalent (FTE) workers. This method is used by the Centers for Disease Control and Prevention (CDC) or the National Institute for Occupational Safety and Health (NIOSH) in fatal injury rate calculations.

Analysis

Multiple analytical approaches were used to provide a comprehensive perspective on the national datasets. Factor analysis was first performed to examine the work system where fatal work injuries occurred. The analysis, using statistical techniques, aimed to indicate key factors that contribute to fatalities. The analysis also aimed to present a system thinking that highlights the interactions among various aspects because no fatal injuries are a result of any single factor [2].

From a safety and health standpoint, breakdowns often occur, within a given aspect, especially at the interfaces between aspects.

In this report, the following five specific system aspects were analyzed to deliver a cohesive picture of the construction work system[3]:

- Environment aspect: the attributes of work environment to indicate when and where fatal work injuries occurred, such as season, time, location, and geographic regions.
- Worker aspect: the attributes of victims to indicate who they were, such as occupation, gender, race, and ethnicity.
- Incident aspect: the attributes of incident to indicate what workers were doing and what happened to them, such as activity, event and exposure, and source of injury.
- Injury aspect: the attributes of injury to indicate what physical consequences were and how severe they could be, such as days of survival, nature of injury, and injured part of the body.
- Management aspect: the attributes of management to indicate the status of employees, employers, and their organizations, such as establishment size, employee status, and work experience.

The trend analysis was performed to identify the longitudinal trajectory in the attributes that contribute to fatal work injuries. The analysis aimed to capture the changes over time as well as the overall trend in construction safety. Then, the comparative analysis was conducted to figure out the similarities and differences in fatality characteristics between residential construction and other construction sectors, such as nonresidential, heavy and civil engineering, and specialty trades. The analysis provided cross-sectional benchmarking where residential practitioners could learn from peers who excel in construction occupational safety and health. Last, the prevention analysis, based on the system ergonomics and the Hierarchy of Controls theory [4], was used to discuss challenges and recommend prevention solutions.

Specific statistical techniques such as frequency analysis, *t*-test, and Pearson's Chi-square tests were used to explore patterns, detect regularities, and finally allow for the generation of conclusions. The narrative text analysis technique was also used to extract useful, hidden information from incident description texts, interpret fatality characteristics, and suggest prevention measures [5].

Disclaimer

Partial data used in this research were from BLS under an agreement with Michigan State University. This research was conducted with restricted access to BLS data. The views expressed here do not necessarily reflect the views of the BLS.

RESULTS

Fatalities

From 2014 to 2018, the average number of fatalities in residential building construction was 121 deaths per year. The average number was consistent with previous research [6]. The fatalities in residential building construction accounted for 12% of that in all construction.

Coupling the industry employment in the same period, the fatality rates were listed in Table 1. The average fatality rate in residential building construction was 10.9 deaths per 100,000 FTE workers, indicating 11% higher than all construction sectors combined and nearly twice of nonresidential building construction.

Table 1. Fatality rates of the construction industry, 2014–2018

Year	Residential Building Construction	Nonresidential Building Construction	All Construction
2014	10.5	6.4	9.8
2015	10.2	5.6	10.1
2016	11.5	4.3	10.1
2017	11.7	4.6	9.5
2018	10.5	5.7	9.5

The growths of fatalities in all construction sectors were listed in Figure 1. The fatal work incidents in residential building construction skyrocketed after 2011, faster than all construction sectors and all goods-producing industries combined. The average growth from 2014 to 2018 was approximately 5% every year in residential building construction.

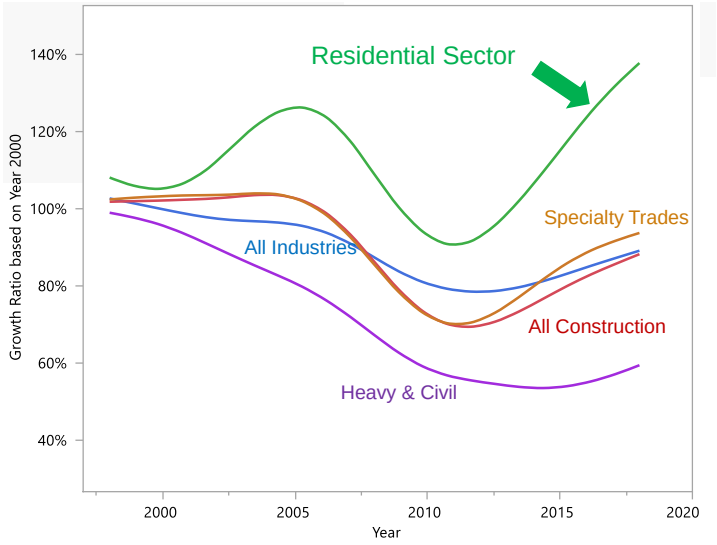

Figure1. The growth of fatalities in construction, 1998-2018

Environments

The analysis of environment aspect represented the attributes of work environment to show when and where fatal incidents occurred. The factors include, for example, season, time, and location.

Regarding the season of incidents, the number of fatalities peaked in summer (June, July, and August), accounting for 32% of all fatalities in the years; bottomed out in winter (December, January, and February), accounting for 20% of all fatalities in the year. Especially, the highest number of fatalities occurred in August (12%) and the lowest number of fatalities occurred in December (6%). The results showed that a large proportion of injuries occurred in the summer months when the industry had many ongoing projects. The results were consistent with the existing research in residential and non-residential construction projects [7].

The weekday distribution of incidents was displayed in Figure 2. The fatality occurrences were dominant on weekdays (88%) and rare on weekends (12%), which was consistent with general work schedules in residential construction. It was noteworthy that 21% of the fatalities occurred on Mondays, indicating difficulty for workers to transit from the rest mode on weekends to the work mode on workdays. This result is slightly different from the past research where fatalities often peaked on Wednesdays [6, 7].

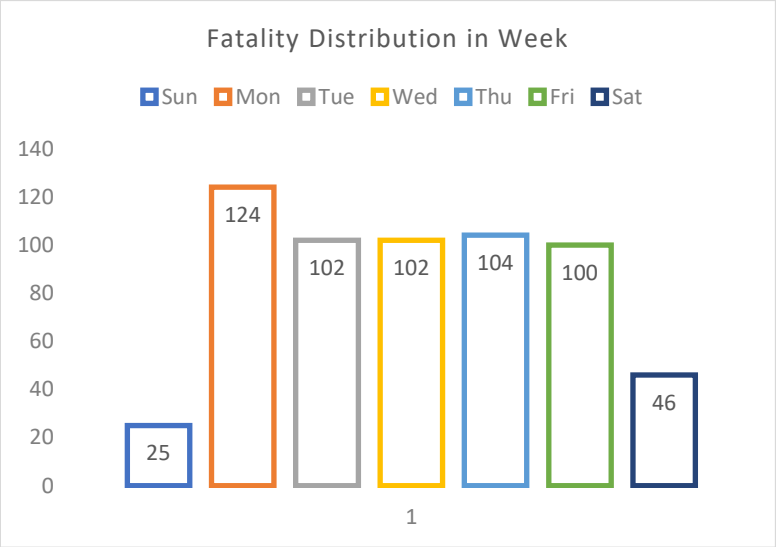

Figure 2. Fatality distribution in the week, 2014–2018

The time-of-day distribution was displayed in Figure 3. The majority of fatalities occurred during work hours between 10 a.m. and 3 p.m. Out of the 485 deaths with a known time, 61% happened in this time interval. The fatal occurrences climbed up until around 1 p.m. and dropped after 3 p.m. in the afternoon.

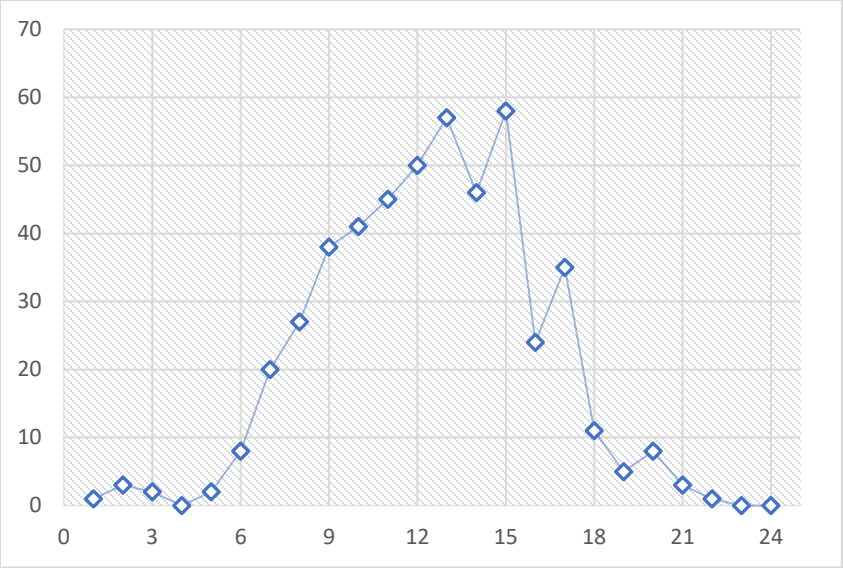

Figure 3. Fatality distribution by the time of day, 2014–2018

The fatality distribution by region was displayed in Figure 4. The difference among census regions was significant where southern states took the highest proportion at 35% and Midwest states took the lowest proportion at 18%. The number of deaths in the South was almost twice that in Midwest. Almost all fatalities occurred in construction project-related locations. For example, 56% of the fatal incidents occurred in residential construction sites and 10% occurred in renovation and remodeling sites.

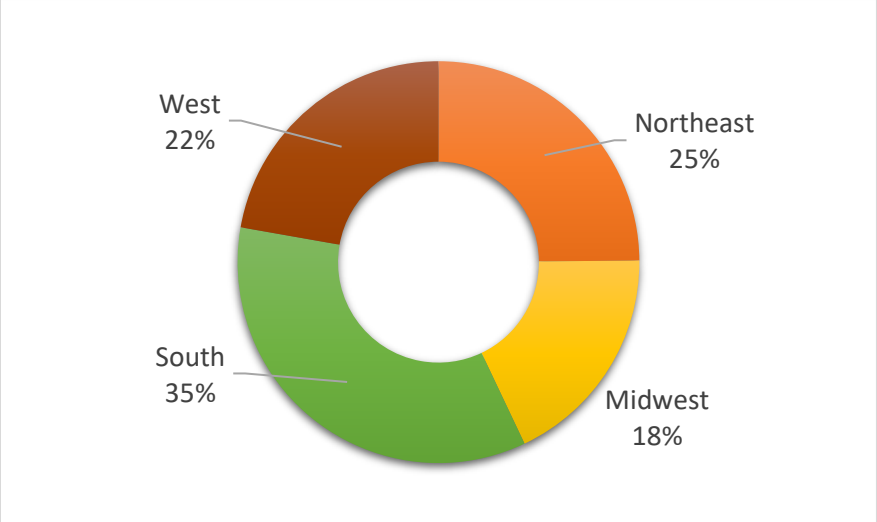

Figure 4. Fatality distribution by region, 2014–2018.

Workers

The analysis of worker aspect represented the attributes of victims to show who they were and what demographic features they could carry.

Almost all fatalities occurred in the construction, extraction, installation, maintenance, and repair occupations. Especially, the highest number of victims were construction laborers (n=243), accounting for 40% of the fatalities in residential building construction. Carpenters (n=131) and first-line supervisors (n=124) were the second and third risky occupations, accounting for 22% and 21% of the fatalities, respectively. The results were consistent with the occupation distribution in previous research.

Nearly all the victims were male by gender. Regarding race, most of them were Caucasian (77%) followed by multiracial (13%), African American (6%), and Asian (2%). The demographic distributions were consistent with previous studies. Regarding ethnicity, 442 victims were non-Hispanic (73%) while 160 were Hispanic (27%). Particularly, only 18% of the white victims were Hispanic.

The fatality distribution by age group was displayed in Figure 5. Workers in the 45–54 age group had the most fatalities at 150 deaths (25%), followed by those in the 55–64 age group at 148 deaths (24%). The results were consistent with the existing studies and indicated an aging workforce in the industry.

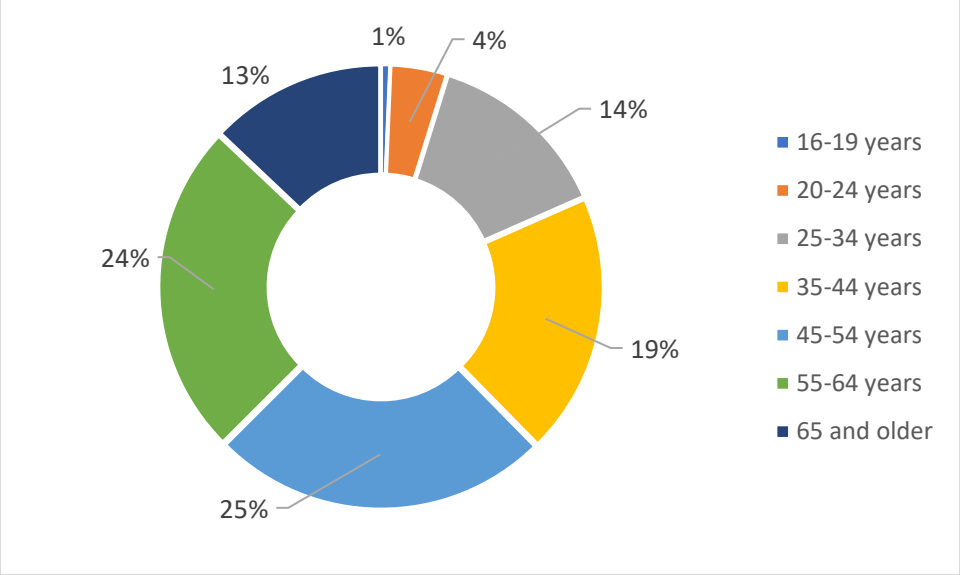

Figure 5. Fatality distribution by age group, 2014–2018

Incidents

The analysis of incident aspect represented the attributes of events and exposure to show what workers were doing and what happened to them.

Constructing activities were associated with the highest number of fatal incidents, accounting for 55% of fatalities (Table 2). The second highest was vehicular and transportation operations, accounting for 14% of fatalities. Specifically, the installing task accounted for 13% of fatalities, being the highest among specific worker activities.

Table 2. List of Worker Activity Groups at Incidents, 2014–2018

Activity Group	Examples	Fatalities	Percentage
Constructing	Building, repairing, cleaning, assembling, installing, painting, moving, etc.	329	55%
Vehicle operations	Driving, riding, boarding, transporting, etc.	83	14%
Physical activities	Climbing, entering, exiting, sitting, standing, walking, jumping, etc.	60	10%
Unknown activities	No records.	60	10%
Machinery	Operating machines, cutting, using tools, reading gauges, valves, welding, trimming, etc.	28	5%
Materials handling operations	Lifting, carrying, holding, loading, packing, etc.	22	4%
Other activities	Other worker activities.	19	3%
Protective service activities	Fighting fire, teaching, training, rescuing, etc.	2	<1%

The event and exposure showed how the injury was produced or inflicted (Figure 6). Falls, slips, and trips remained the top event and exposure, accounting for 52% of fatalities. Falls to a lower level were a critical cause, the majority of which were from the sources of ladders, roofs, scaffolds, structural steel, trees, stairs, and non-moving vehicles. The detailed sources of injury were discussed in the next paragraph. Specifically, falling from the 11–15 f.t. height peaked in the exposure (16% of falls) followed by the 6–10 f.t. height (13%) and 16–20 f.t. height (11%). Surprisingly, exposures to harmful substances or environments increased to be the second riskiest event, accounting for 16% of fatalities. The exposures indicated the abuse of drugs and alcohol. Transportation incidents accounted for 12% of fatalities, ranking as the third riskiest event.

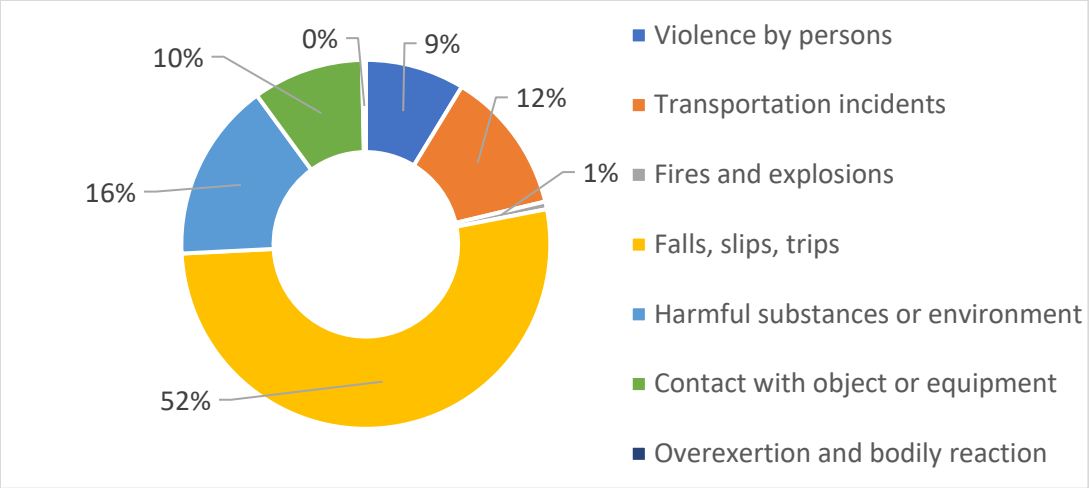

Figure 6. Fatality distribution by event and exposure, 2014–2018.

The source of injury showed the object, substance, or bodily motion that produces injury. The distribution of source was displayed in Figure 6. Structures and surfaces were associated with the most fatalities (37%), followed by chemical products (18%) and vehicles (15%). The highly ranked single sources were roof edge (8%), pickup truck (6%), general ladders (5%), extension ladders (5%), potable ladders (5%), scaffolds staging (4%), and general roofs (3%). Noteworthy was that chemicals took over vehicles and ranked the second highest in the source of injury. Most of the chemicals referred to drugs and alcohol such as methamphetamine, cocaine, fentanyl, methyl, and synthetic opioid.

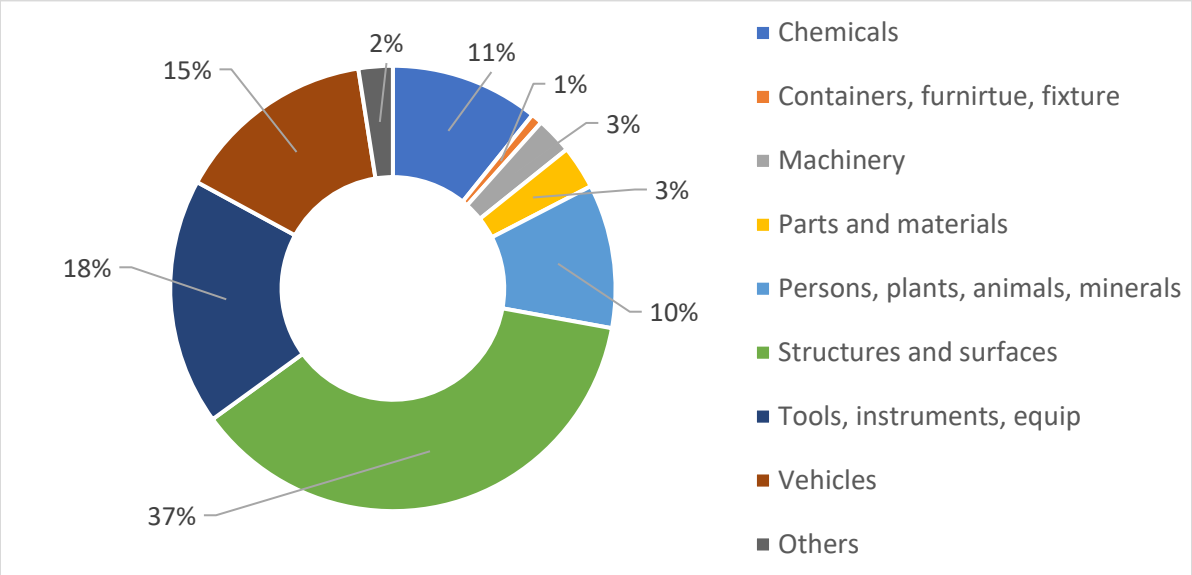

Figure 7. The fatality distribution by source, 2014–2018.

Injuries

The analysis of injury aspect represented the principal physical consequences of incidents to show what the physical injuries were and how severe they could be.

Regarding survival days, 69% of fatalities occurred the same day as the incidents happened, and 89% of fatalities occurred within a week after the incidents. The results were consistent with existing studies and showed the significant severity of construction incidents.

The most significant nature of injury was about intracranial injuries, namely traumatic injuries to the cranium or skull and the structures within (n=91). Another significant injury was about multiple traumatic injuries which were the combinations of multiple traumatic injuries or disorders from more than one major group within this division when they were of equal severity (n=77). The next significant injury was the poisoning or toxic, noxious, or allergenic effects resulting from short-term exposures to chemicals, venoms, drugs, medicines, food, and other substances (n=66). Most of the poisoning fatalities were due to drug intoxication or drug overdose; while a few were due to carbon monoxide during generator operations, for example, in the basement.

Regarding the injured part of the body, head was the most vulnerable part and accounted for more than 37% of fatalities. The various body systems were the second most vulnerable and accounted for more than 33% of fatalities.

Management

The analysis of management aspect represented the attributes of establishments and human resources, showing the status of employees, employers, and their organizations.

Small-sized construction firms with 10 or fewer employees dominated in fatal incidents and accounted for 87% of the firms with a reported establishment size (Figure 8). The proportion of small-sized firms showed a slight increase compared to that in the past years [6]. Nearly all the firms involved in fatalities were private businesses.

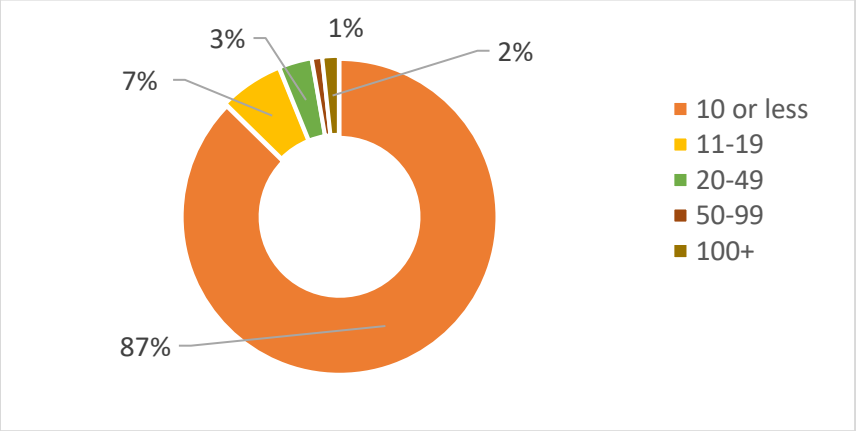

Figure 8. Fatality distribution by firm size, 2014–2018.

Regarding the employee status, 379 of the fatally injured workers were working for pay or compensation (63%) and 209 of them were self-employed (35%). Based on the limited information on employee experience, the majority of victims had one year or less of working experience (30%). It was notable that some victims even had as long as 39 years of working experience in the industry.

Notable Changes

The data analysis was also performed to identify significant changes across the years 2014–2018. The results demonstrated that most of the analyzed factors were stable and consistent during the reporting period, except for four factors: the worker activity, event and exposure, source of injury, and nature of the injury.

A significant change was identified in worker activity from 2014 to 2018. The change indicated an increase in "other activities" (Figure 9), of which 70% were associated with fatalities due to drug toxicity. In addition, the results suggested a slight increase in the installing task as a specific constructing activity.

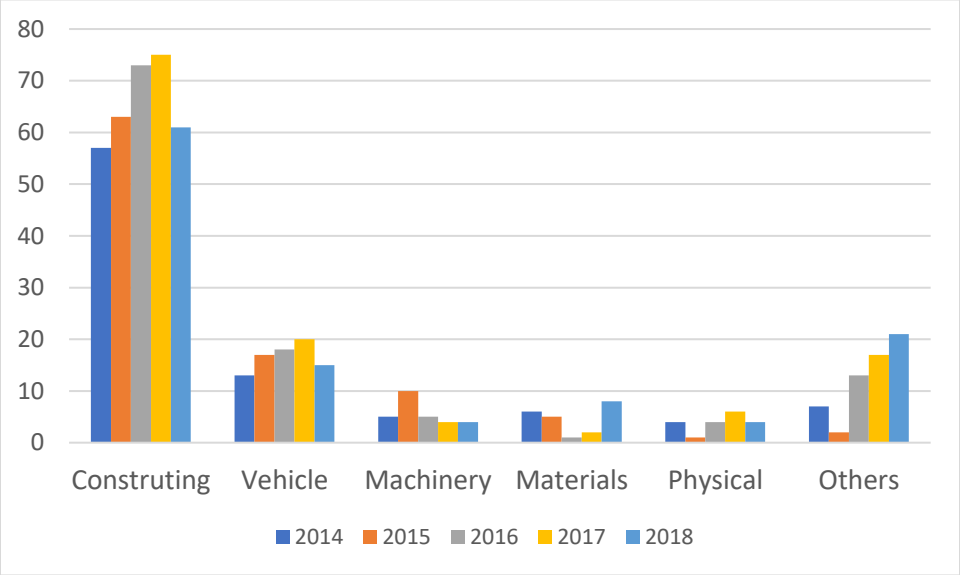

Figure 9. Changes in worker activity in fatal incidents, 2015-2018

The source of injury demonstrated a significant change between 2014 and 2018 (Table 3). The change indicated an increase in chemical products, from 2% in 2015 to 15% in 2018. The event and exposure also reflected a slight change, showing an increase in fatal exposures to harmful substances, which accounted for 13% of fatalities in 2014 and 19% in 2018. Similarly, the change in the nature of injury demonstrated a continuous increase in poisoning, toxic, and noxious effects, particularly the drug intoxication. Those poisoning cases doubled from 2014 to 2018. All the above changes together implied a trend of increasing drug and alcohol use that

caused worker deaths in residential construction. Most of the poisoning-related workplace fatalities, unfortunately, were not relevant to producing activities.

Table 3. Changes of Source Proportions for fatality, 2014–2018

Source	2014	2015	2016	2017	2018	Average
Chemicals	8%	2%	11%	16%	15%	10%
Containers	1%	1%	0%	1%	2%	1%
Machinery	3%	1%	5%	1%	3%	3%
Materials and parts	6%	2%	2%	4%	2%	3%
Persons and animals	15%	5%	11%	11%	10%	10%
Structures and surfaces	33%	41%	35%	41%	36%	37%
Tools and equipment	19%	23%	20%	12%	17%	18%
Vehicles	15%	18%	15%	13%	13%	15%
Others	1%	7%	2%	1%	2%	3%

DISCUSSION

Comparisons

The comparative analysis showed similarities and differences in the fatality characteristics between the residential building construction sector and other construction sectors. Table 4 displayed the factors that significantly changed during the analysis period. In other words, these factors are not stable in the work system. Overall, most fatality characteristics in residential construction were stable, especially in terms of the work environment, workers, and management. The major changes, as reported in the previous section, indicated a trend of increasing fatalities by drug intoxication.

Table 4. Unstable Factors among Construction Sectors, 2014–2018

Sector	Environment	Worker	Incident	Injury	Management
Residential			X	X	
Nonresidential		X			
Heavy & Civil	X	X	X	X	X
Specialty Trades			X	X	

It was notable that being stable may not always be a good signal because the stability of fatality characteristics could suggest that existing problems never get resolved. For example, the occupation of the victims was stable in residential construction; however, such stability could reflect that the vulnerable status for certain occupations, such as construction laborers or carpenters, has not been significantly improved. In comparison, the heavy and civil engineering sector demonstrated many changes in every aspect of the work system, for example, the project location, occupation, exposures, nature of the injury, and firm size; while the heavy and civil engineering sector delivered the lowest fatality growth as previously illustrated in Figure 1.

Preventions

The prevention analysis, based on system ergonomics and the Hierarchy of Controls theory [8], found that most fatality characteristics remained the same for years in the residential construction sector. Thus, prevention should particularly focus on these long-lasting factors.

Falls from height continued to be a leading cause in residential fatality statistics, regardless of increasing awareness of fall prevention. The major sources of fall fatalities are simple structures and tools such as roof edges and extension ladders. It seems no complicated engineering systems, machines, or technologies deem to be necessary. Instead, the efforts on prevention through design (PtD) are recommended [9]. Notably, PtD solutions, which aim to “design out” hazards from the work environment or process, can be simple and affordable for home builders. The key of PtD adoptions is to systematically comprehend the effects and interactions of the work environment, specific tasks, worker features, and management. Low-cost, accessible, and effective training and

education efforts, for example, through short videos in mobile phone app, can help build a safe climate among construction workers, employers, and safety professionals on fall protection [10].

Residential building contractors and professional associations should track and compare the causes of incidents and near misses. Responsible interventions should be designed and executed accordingly. For example, the findings of this study have identified a trend of fatalities due to drug overdose, although the amount of fatalities is not very large. Attention and actions are required to truncate the trajectory. Drug and alcohol use can be related to workers' mental health issues due to the tight project schedule, high pressure and workload, or others. This, on the other side, can be linked to insufficient training and management in the industry.

Extra supports are necessary to communicate the added risk to small-sized residential contractors under 10 employees. It is important to help the smaller contractors or sub-contractors establish culture, policies, and procedures. For example, a benchmarking process can help explore and identify the best practices associated with larger contractors that can be adopted or adapted by smaller home builders.

Safety training remains critical for home building workers to create awareness about the increased safety concerns, especially related to an aging workforce. Communication and training need to be emphasized that obtaining more experience as one ages does not necessarily reduce the risk of fatalities. Therefore, there is a need to be vigilant about safety every day.

CONCLUSIONS

The fatality rate in the residential building construction sector is higher than the fatality rate in the construction industry as a whole and is almost twice as nonresidential. A trend appears showing a fast-growing number of fatalities in the residential construction sector. Falls to a lower elevation, especially from roofs, ladders, and scaffolds, continue to be the leading cause of death in residential construction. This fall protection problem has been the same for decades in the residential building sector. Also, the use of drugs and alcohol becomes an emerging cause of death in residential construction. Such new changes require special caution from home builders to prevent drug intoxication. Small-sized home builders remain the vulnerable core of fatal incidents. Construction laborers, carpenters, and first-line supervisors or managers are the top risky occupations. An aging workforce in residential construction remains a problem and diverse race groups emerge. Fatality-related factors in the residential building sector are overall stable compared to other construction sectors, while it may imply less improvement on these existing problems. Therefore, systematic solutions are recommended to comprehensively consider the effects and interactions of the work environment, specific tasks, worker features, and management.

To be noted that all the data analyses are based on fatality data before the COVID-19 pandemic which could dramatically reshape the safety landscape of the industry. Future research needs to characterize the changes during the pandemic and predict the trajectory in the post-pandemic era.

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