Understanding the Current State of Safety Hazards in the Crane Industry

nsc National Safety Council | NCCCO FOUNDATION

Contents

Executive Summary

The Work to Zero initiative at the National Safety Council (NSC) partnered with the NCCCO Foundation to survey certified crane operators and inspectors regarding safety hazards in the crane industry. The goal was to identify the most common hazardous situations these workers are exposed to, the main causes (i.e., situational risks) and contributors (i.e., systemic risks) to workplace injuries, and to understand their use and perceptions of safety technology solutions used to eliminate or mitigate these risks.

Key Findings

1. Survey participants reported work at height, vehicle-pedestrian interactions, and loading and unloading materials as the hazardous situations they were most likely to be exposed to when on the job. Between 55% and 89% of participants said they were likely or very likely to be exposed to these hazardous situations. In 2020, NSC found these three hazardous situations resulted in 30% of non-roadway occupational fatalities.

2. The two most common situational risks directly causing injuries were falls from height and being struck by a falling object, both of which are part of OSHA's Focus Four Hazards.

3. The two most common systemic risks contributing to injuries were heat stress and fatigue. These risks were also considered to be some of the most likely exposures reported by participants.

4. Over 80% of survey participants believe they have access to appropriate safety training before starting a task, but lack of proper training still accounted for seven percent of personal injuries and eight percent of site injuries.

5. Overall, the use of safety technology is fairly low. Depending on the specific type, only one to 13% of participants reported currently using technology at the job sites where they are working. The most commonly used technologies were proximity sensors, wearables for vital signs monitoring and drones.

6. Despite low use rates, survey participants' responses indicated a general willingness to try new safety technology solutions. Common responses regarding potential benefits described improved safety, reduced blind spots, and the ability to alert both workers and others of job site hazards. One of the most frequently reported barriers to using safety technology was concern over data privacy.

Background and Objectives

The goal of the Work to Zero initiative at NSC is to eliminate workplace fatalities by helping employers implement safety technology. The NCCCO Foundation was formed by the National Commission for the Certification of Crane Operators (NCCCO) in 2018 to promote safety in the crane industry through three pathways: education, research, and workforce development. NSC and the NCCCO Foundation partnered to develop data-driven content for individuals working in and around cranes and their employers to increase the awareness of risks and highlight technology solutions to reduce serious injuries and fatalities.

The Census of Fatal Occupational Injuries (CFOI) reported 297 crane-related deaths between 2011 and 2017. Over 50% of these fatalities involved workers being struck by objects or equipment. Falls accounted for an additional 14% of fatalities, and transportation incidents accounted for 13% (BLS, 2023). To understand the current state of safety hazards in the crane industry, NSC and the NCCCO Foundation surveyed workers with NCCCO certifications (e.g., operators, riggers, signalpersons) about their most likely exposures, and the causes and contributors to workplace injuries. Additionally, survey participants were asked questions about safety preparedness and policies at their job sites, as well as their preferred modes for safety training. Lastly, operators were asked questions to gauge industry awareness of, and experience using, safety technology. This report summarizes key findings from the survey.

Methodology

The survey was adapted from a 2020 Work to Zero survey used to understand and track safety technology use and needs in the workplace (National Safety Council, 2020). The original survey was deployed across seven major industries. For this project, questions were revised to incorporate language more specific to crane operators and those working in the crane industry. Questions were reviewed by members of the NCCCO Foundation Board to ensure validity.

The survey was sent to the NCCCO distribution list (approximately 100,000 recipients) on July 12, 2023, and remained open until August 2, 2023. To participate in the survey, respondents were required to have an active certification through NCCCO and to have worked, using their certification, in the last 24 months. The survey was voluntary, and all responses were anonymous. Participants were allowed to skip any questions they chose not to answer. Upon completion of the survey, participants had the opportunity to enter to win one of 20 $25 gift cards as an incentive. The survey was reviewed by the NSC Institutional Review Board and declared exempt human subjects research.

Responses were collected via Qualtrics (Qualtrics, Provo, UT) and downloaded for analysis into Microsoft Excel (Microsoft Corporation, Redmond, WA). Survey questions were comprised of both multiple-choice and open-ended response options. Basic descriptive statistics were used to summarize job hazards and technology perceptions. Open-ended responses were reviewed by the WTZ research team to identify any themes relevant to the perceived benefits and barriers of using safety technologies.

Results

There were 2,320 responses to the survey. Of the 2,320 responses,150 were screened out: 14 had no active certification and an additional 136 had not worked using their certification in the last 24 months. Thus, 2,170 responses were included in the survey analysis. Since participants were allowed to skip questions, there were not always 2,170 responses for each question. Participants ranged in experience from being certified for less than one year (8%) to being certified for over 20 years (10%). Most participants (29%) reported having been certified for one to five years (Figure 1).

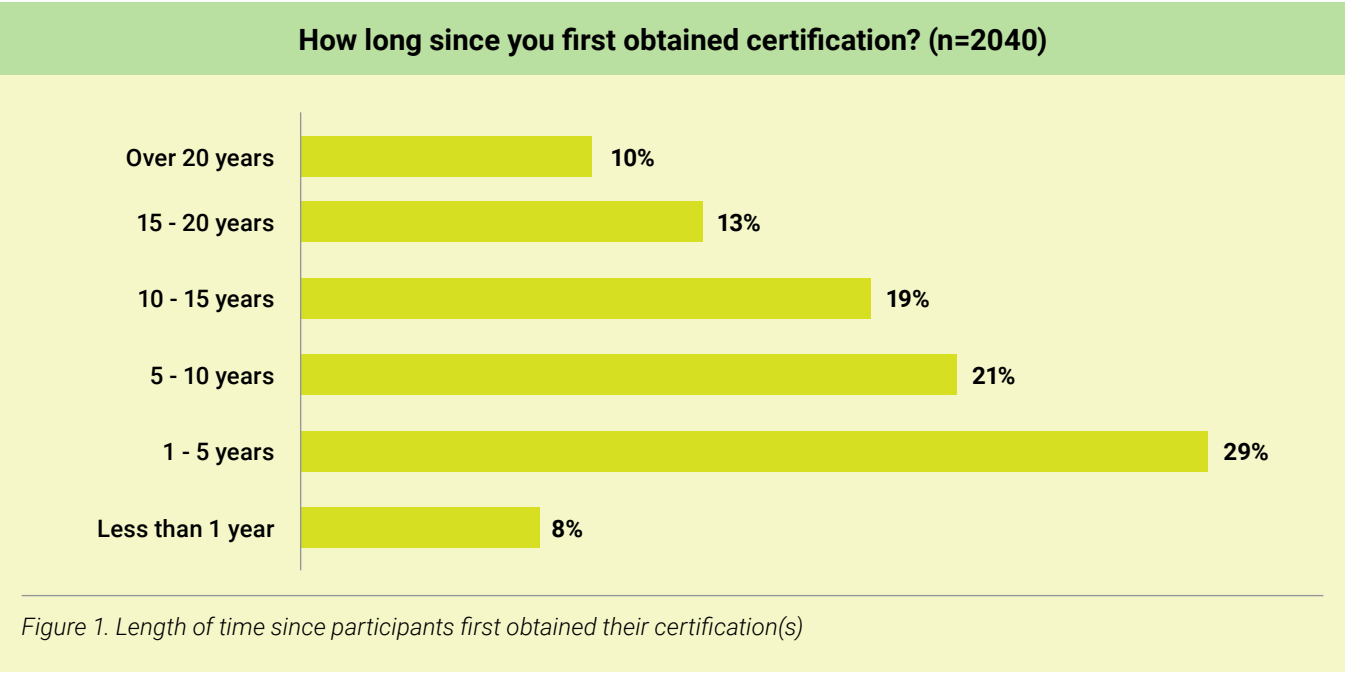


Figure 1. Length of time since participants first obtained their certification(s)

Participants were located across the country with the most respondents in the South Central region (28%), North Central region (21%) and the South Atlantic region (18%) (Figure 2). States were grouped into regional areas to better account for workers who may have worked at job sites in multiple states. Seventy-five percent of participants reported working in the Construction industry, ten percent in Utilities, three percent in Manufacturing, two percent in Mining/Quarrying, and less than one percent in Transportation and Warehousing, Agriculture and Wholesale Trade (Table 1).

Table 1. Percentage of participants by primary industry and primary role

Primary Industry	Participants (%)	Primary Role	Participants (%)
Construction	75	Operator	85
Utilities	10	Site Supervisor	6
Manufacturing	3	Rigger	3
Mining/Quarrying	2	Trainer	3
Transportation and Warehousing[1]	1	Signalperson	2
Agriculture	< 1	Crane Inspector	<1
Wholesale Trade[2]	< 1	Lift Director	<1

[1]Transportation and Warehousing includes Maritime and non-Maritime.
[2]Wholesale Trade includes metals recycling.

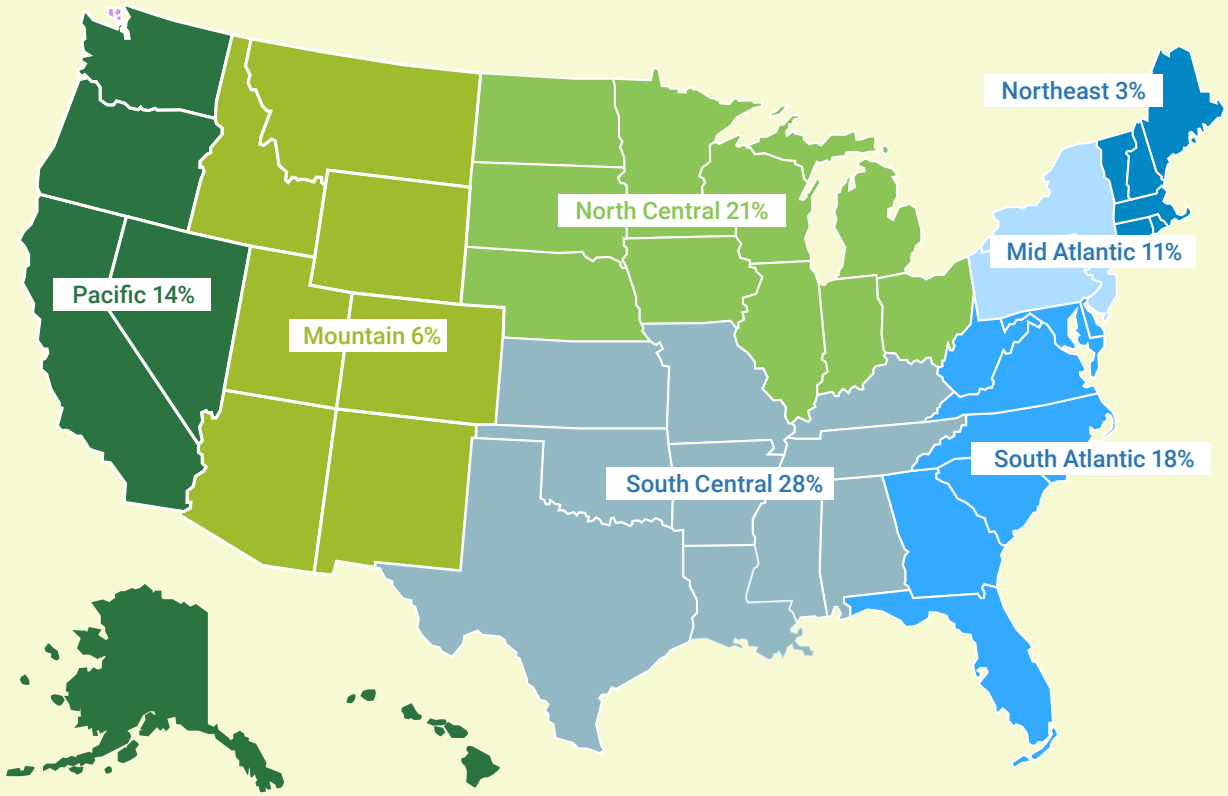
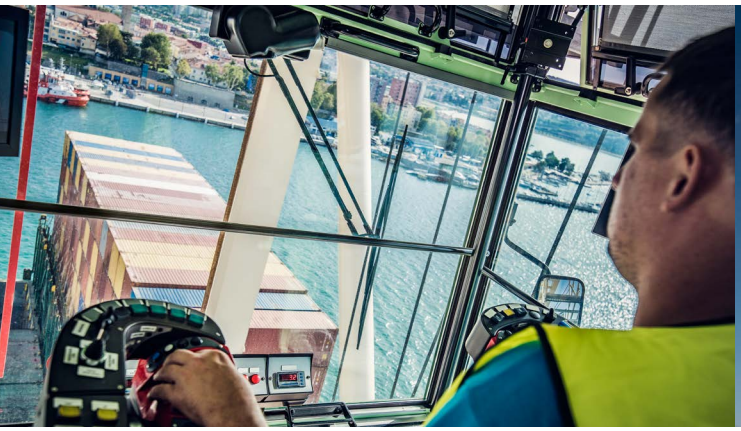


Figure 2. Map illustrating regional location of survey participants

Eighty-five percent of respondents reported their primary role as Operator (Table 1). The most common certification reported was Mobile Crane Operator (36%), followed by Rigger (13%), Signalperson (11%) and Service Truck Crane Operator (11%) (Table 2). Over half of the participants (58%) had multiple certifications. The 2,170 participants who responded to the certification question reported a total of 5,156 certifications, averaging 2.4 certifications for each respondent.

Table 2. Self-reported participant certifications (n=5,156 certifications)

Certification	Percent
Mobile Crane Operator	36
Rigger	13
Signalperson	11
Service Truck Crane Operator	11
Articulating Crane Operator	7
Telehandler Operator	6
Overhead Crane Operator	5
Tower Crane Operator	5
Digger Derrick Operator	2
Lift Director	2
Dedicated Pile Drive Operator	1
Crane Inspector	1
Drill Rig Operator	1
Concrete Pump Operator	<1



Job Hazards

In 2020, using data from the Bureau of Labor Statistics (BLS) and CFOI, Work to Zero identified the top hazardous workplace situations across industries in which non-roadway occupational fatalities were occurring (NSC, 2020). Additionally, WTZ identified situational and systemic risks contributing to these fatal injuries.

A hazardous workplace situation is defined as any situation where work is performed with the potential for a serious injury or fatality to occur. Situational risks are the risks inherent to the situation or the proximate cause of injury. Systemic risks, or systemic factors, contribute to injuries but are not the direct cause. For instance, if working at height is a hazardous situation, then falls to a lower level may be considered a situational risk, and fatigue or adverse weather may be a systemic factor.

Survey participants were asked about the likelihood they would be exposed to different hazardous situations and risks while working using their certification(s). Participants reported that the top three hazardous situations they were likely or very likely to be in were loading and unloading (89%), vehicle-pedestrian interactions (64%) and working at height (55%). Situational risks associated with loading and unloading activities include falls to lower levels, being crushed by moving loads, and being struck by vehicles or machinery and equipment. Situational risks associated with vehicle-pedestrian interactions include being struck, crushed or pinned by a vehicle. Situational risks associated with work at height include falls to lower levels, falls at the same level and being struck by falling objects.

Systemic risks that may be associated with all these situations include lack of proper training, fatigue, lack of workplace awareness (e.g., being unfamiliar with job surroundings), adverse weather and heat stress from working in high-heat environments. Although heat stress is often considered to be an illness, it can also contribute to injuries and is therefore classified as a systemic risk in this report. High-heat environments can increase risk and contribute to injuries (e.g., excessive sweat on the palms may cause someone to lose their grip, fogged safety glasses may lead to trip hazards, dizziness from heat stress may cause falls) (AIHA, 2023).

Figure 3 illustrates the top situational and systemic risks that survey participants reported as their most likely exposures. Participants were asked "Thinking of the jobs you do with your certification, how likely are you to be exposed to the following?" Each risk was listed separately, and participants responded as very likely, likely, unlikely or very unlikely. Fatigue and heat stress were reported to be the most common risks that participants are exposed to at work. Top situational risks included being struck by a falling object (55%) and equipment overturn or tipping (53%).

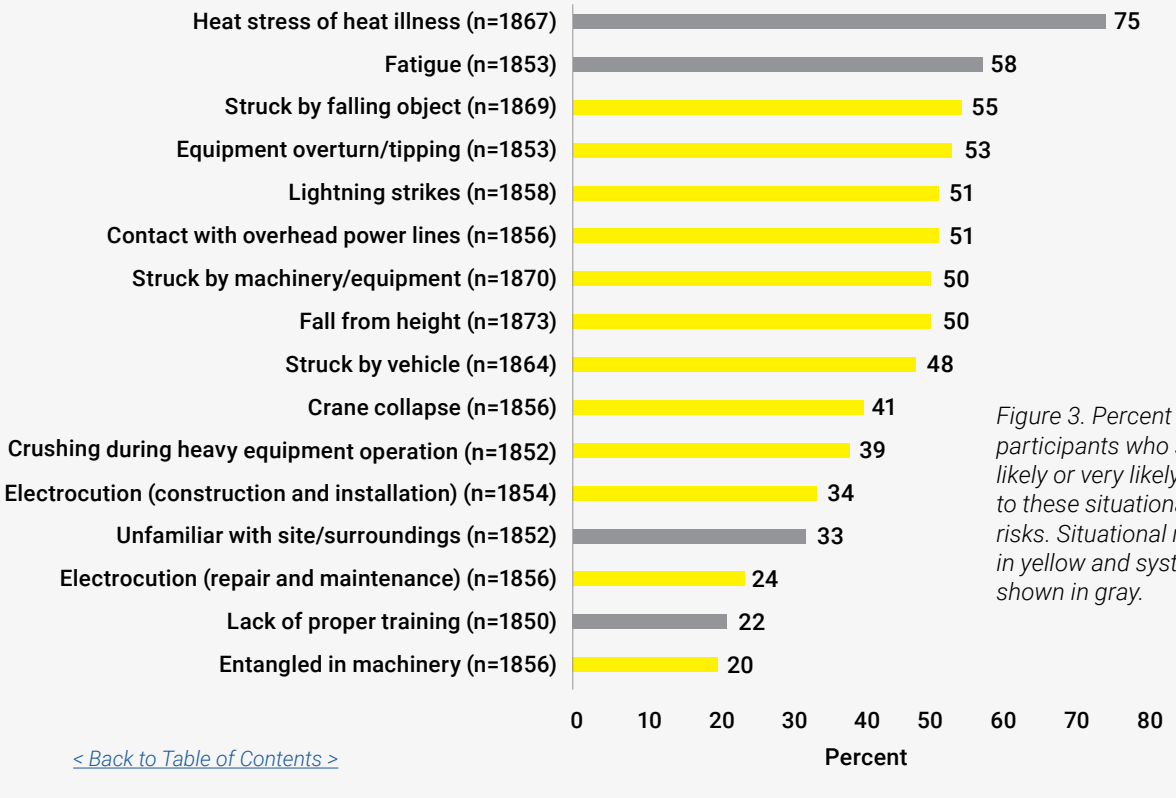


Figure 3. Percent of survey participants who said they were likely or very likely to be exposed to these situational and systemic risks. Situational risks are shown in yellow and systemic risks are shown in gray.

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Survey participants were also asked about which risks contributed to injuries at their job site(s) in the past two years. They were asked about any injuries that occurred on the job site(s), as well as personal injuries. 1,748 participants responded to the question "Which of the following have caused or contributed to a serious workplace injury at your job site(s) in the last 24 months?" Of those, 32% responded "none of these." The remaining 1,193 participants identified 4,482 risks associated with injuries on their job sites. 1,681 participants responded to the question regarding personal injuries: "In the last 24 months, have you personally experienced an injury on the job due to any of the following?" Eighty percent (1,346 participants) reported they had not experienced any personal injuries in the last 24 months. The 335 participants who reported experiencing a personal injury identified a combined total of 732 risks that contributed to those injuries.

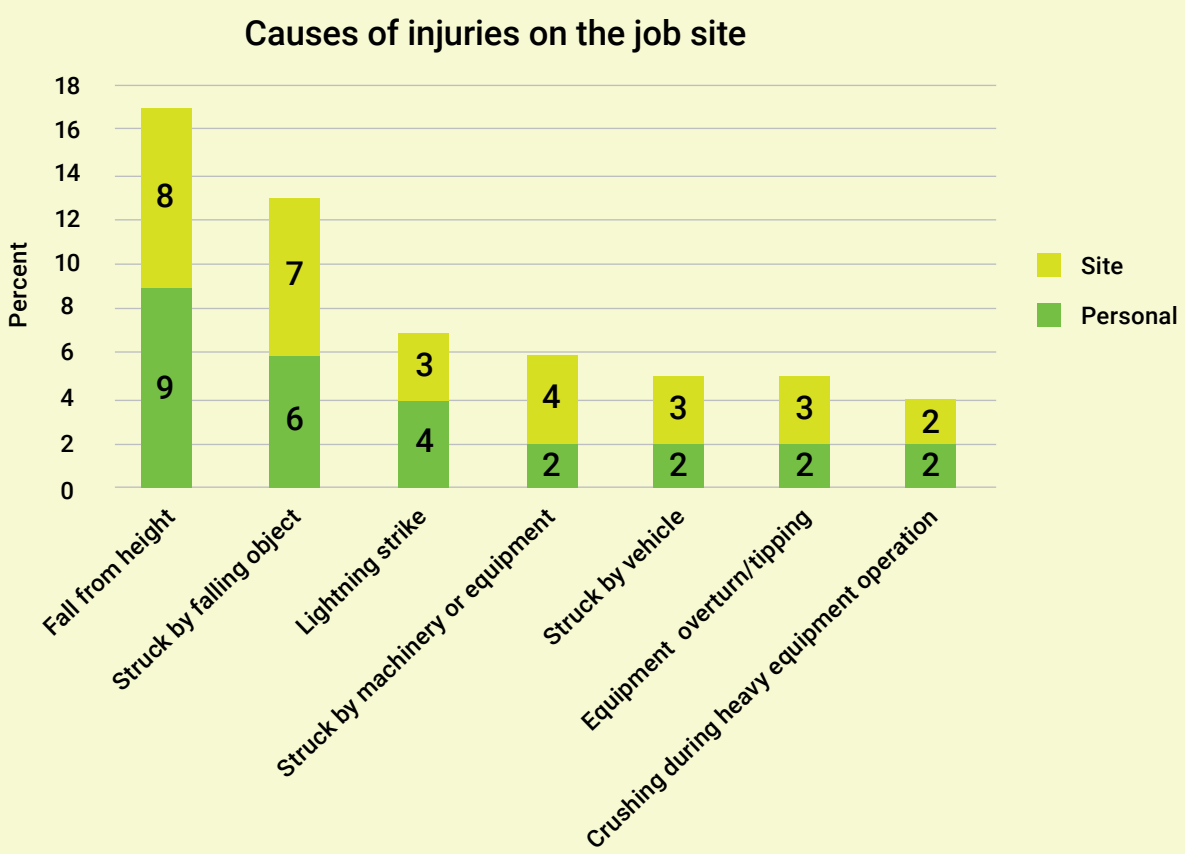

Figure 4. Breakdown of the percent of situational risks that caused either a personal injury or any injury on the job site in the last two years. There was a total of 4,482 risks attributed to job site injuries, and 732 risks attributed to personal injuries. For example, falls from height were reported as the cause of 9% of all of the personal injuries that participants reported in the last two years.

The most frequently reported contributor to injuries was falling from height, which accounted for 9% of personal injuries and 8% of site injuries (Figure 4). Being struck by a falling object was the second most common cause of injury reported. Participants reported both fatigue and heat stress as the most common systemic risks contributing to personal injuries (18%) and heat stress as the most common contributor to injuries experienced by others on the job site (16%) (Figure 5).

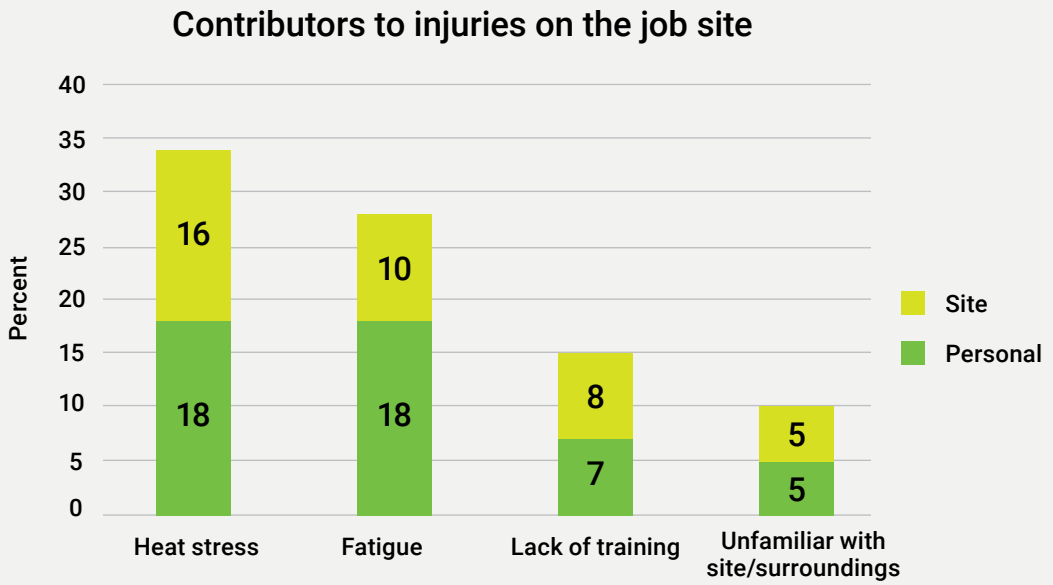

Figure 5. Breakdown of the percent of systemic risks that contributed to either a personal injury or any injury on the job site in the last two years. For example, fatigue was considered a contributing factor in 18% of all the personal injuries reported by participants.

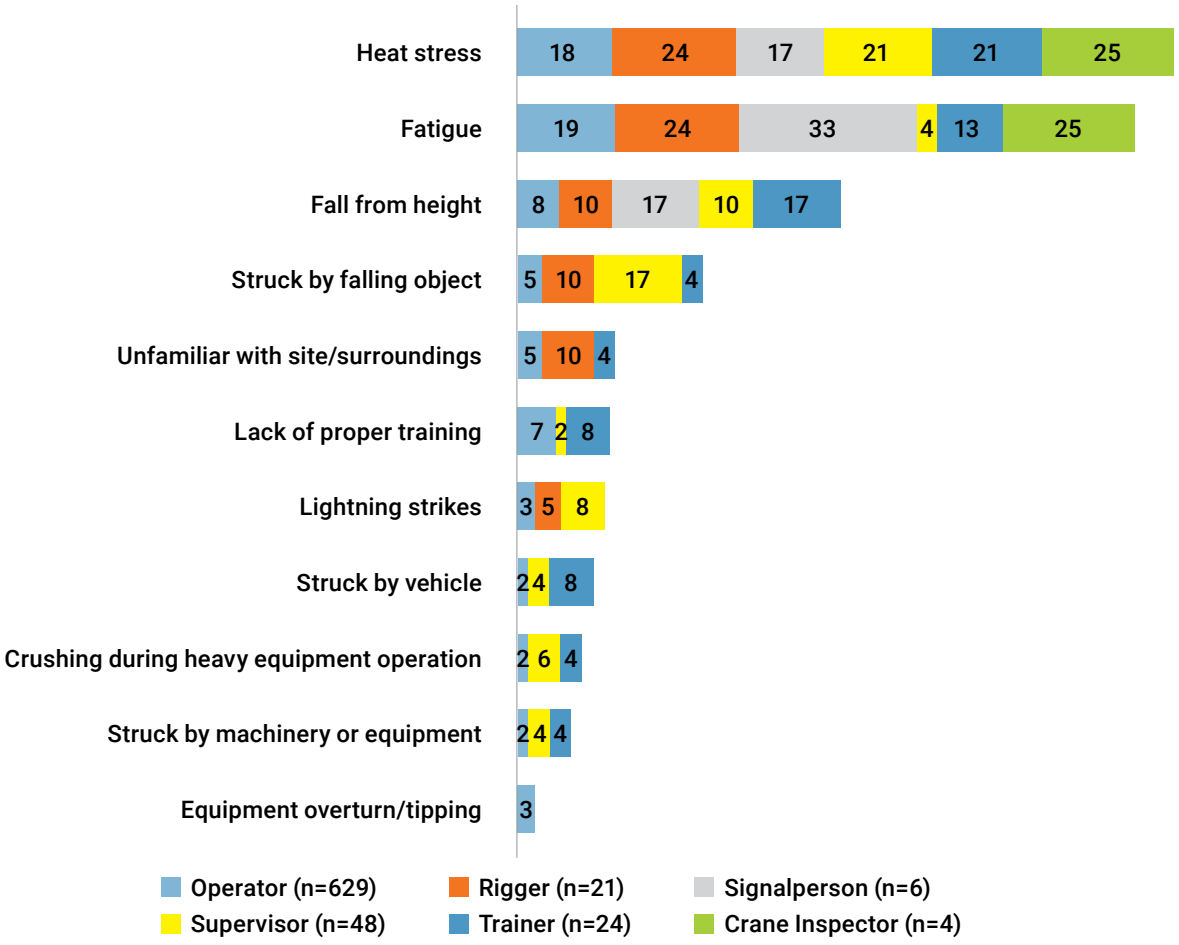

Figure 6. Breakdown of the top causes and contributors to personal injuries by primary role. Numbers represent the percentage of total personal injuries by role attributed to each risk. For example, heat stress was reported as a contributor to 18% of the 629 personal injuries reported by operators.

Figure 6 illustrates the breakdown of which risks participants reported caused or contributed to a personal injury by primary role. Both heat stress and fatigue were the most common contributors to personal injuries for all job roles. Operators were the only group to report equipment overturn and tipping as a cause for injuries. A higher percentage of riggers' injuries were attributed to being unfamiliar with the site than other groups, and supervisors reported a higher percentage of injuries from being struck by falling objects than other groups. Trainers and signalpersons reported more injuries from falls from height. Trainers also reported a higher percentage of injuries due to being struck by vehicles, and notably, from a lack of proper training, than the other groups. There were no personal injuries reported by Lift Directors. It is important to note the majority (85%) of survey participants identified their primary roles as "Operators," so risks reported by smaller groups may be less representative of their respective populations.

Causes and contributors to personal injuries were also analyzed by region. Again, fatigue and heat stress were the most frequently reported contributing factors to personal injuries. The highest reports of heat stress were in the South Central region (28%) and heat stress was not reported in the Northeast. For all other regions, between 21 and 26% of participants reported heat stress as a contributing factor to a personal injury.

Sixty percent of participants in the Northeast reported fatigue as a contributing factor to a personal injury, while 20 to 25% of participants in all other regions reported fatigue. This substantial difference is likely due to the low number of participants in the Northeast region (3%). The Pacific region reported the highest number of overturn injuries (8%) and the highest number of injuries due to lack of training (14%). Lightning strikes were most frequently reported in the South Central region (9%) compared to other regions where they accounted for between 0 and 6% of injuries.

Preparedness, Policy and Training

Overall, survey participants' responses indicated feeling prepared to work safely and that jobsites had policies in place to keep people safe at work. The majority of participants (84%) said they strongly agreed or agreed, 57 and 27%, respectively, that their jobsites have continuous improvement processes to reduce incidents and injuries. Eighty-five percent agreed (67% strongly agreed and 18% agreed) that their jobsites routinely track and monitor serious injuries, fatalities and near-misses (Figure 7). When asked about their supervisors, 58% strongly agreed and another 28% agreed their supervisors can identify potential safety issues and 60% strongly agreed and 26% agreed there are quality procedures for their supervisors to follow once they have identified safety issues.

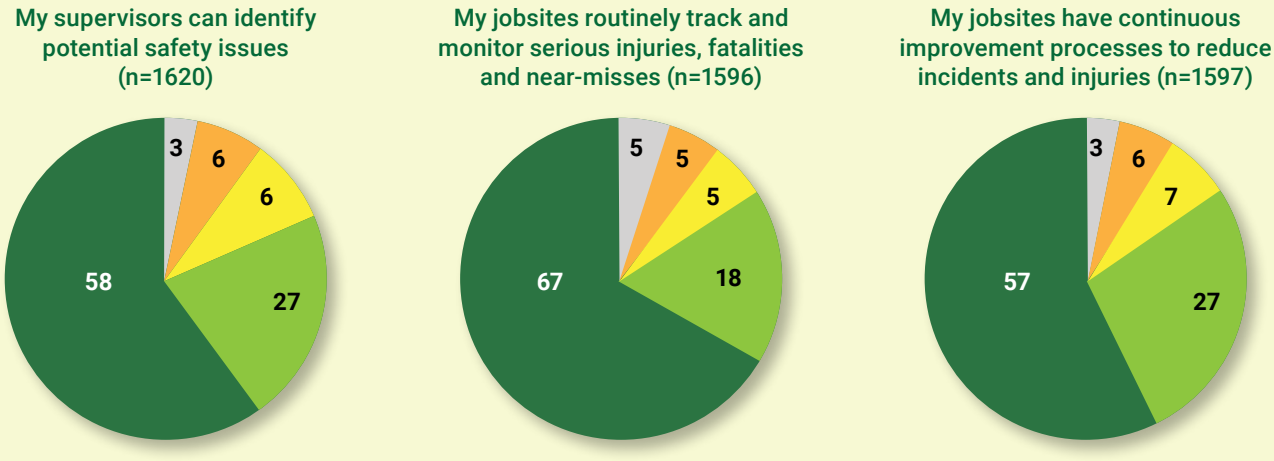

Figure 7. Pie charts illustrating participants' agreement with statements about their job sites and supervisors. Colors represent responses as follows: dark green (strongly agree), green (agree), light yellow (disagree), dark yellow (strongly disagree) and gray (not applicable).

When asked about incident reporting, most participants agreed that their job sites encouraged incident and near-miss reporting. The majority of participants also indicated they always report incidents that result in injuries to their supervisors. However, there was a substantial decline in agreement about reporting near-misses (Figure 8).

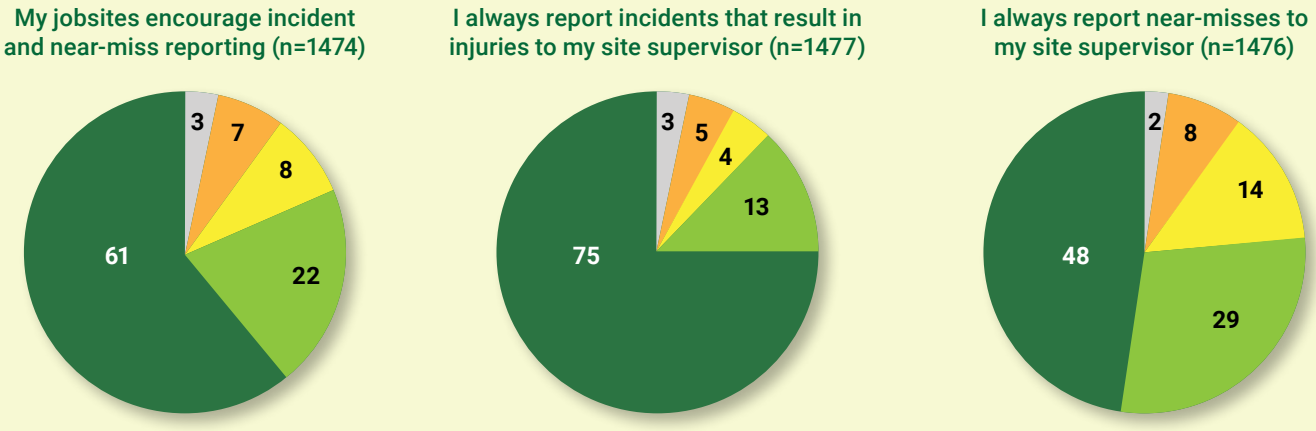

Figure 8. Pie charts illustrating participants' agreement with statements about reporting incidents. Colors represent responses as follows: dark green (strongly agree), green (agree), light yellow (disagree), dark yellow (strongly disagree) and gray (not applicable).

Encouragingly, 86% of survey participants reported they feel very confident they can identify potential issues. Eighty-nine percent felt very confident they could stop work if they felt unsafe, and 84% were very confident they could discuss their safety concerns with their supervisors. Most participants (82%) also reported they felt they had access to appropriate training before starting a task (Figure 9).

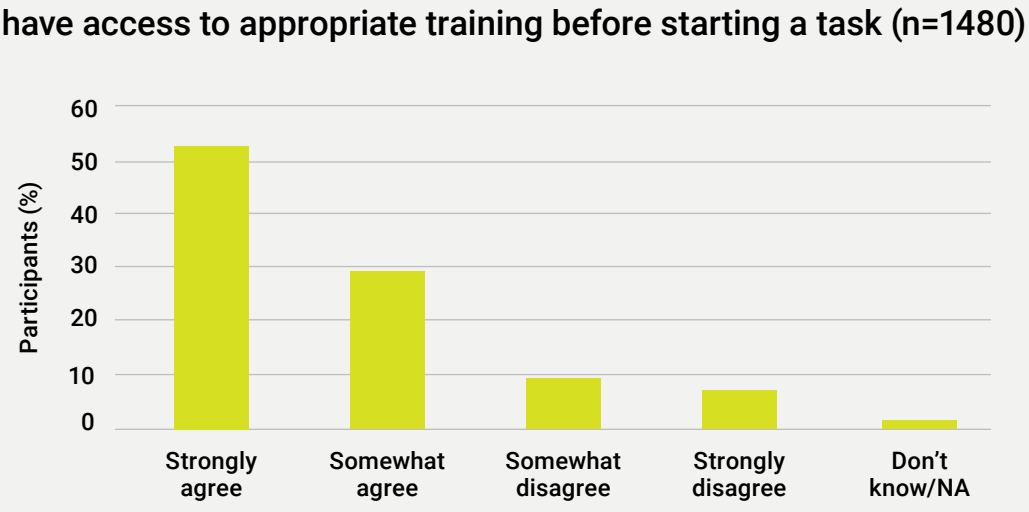

Figure 9. Percent of participants responding to a question about access to safety training

Participants were also asked what mode of training they preferred for safety content. They were asked to rank the options listed from most preferred (1) to least preferred (5) or write in their preference for any other formats. All participants, regardless of age or role, generally answered the same way with the greatest preference for in-person training options (Table 3). Open-ended responses regarding preferred modes of training emphasized the importance of hands-on safety training and working with instructors who had experience with various hazards. One participant said, "No amount of classroom training can fully train for real work experience." Mentorship was also mentioned by numerous survey participants who reported it was a great way to learn on the job.

Table 3. Description of preferred methods of training as reported by participants (n=1,055). Training formats were ranked from 1 (most preferred) to 5 (least preferred). The average, standard deviation and mode are reported in the table below.

Mode of training	Average Rank (SD)	Mode
In-person training (on-site)	1.6 (1.2)	1.0
In-person training (classroom)	2.3 (1.1)	2.0
Online training	3.5 (1.2)	3.0
Visuals (e.g., posters, infographics, handouts)	3.9 (1.0)	4.0
Videos	4.0 (1.1)	5.0

Safety Technology

Participants were asked about their overall level of familiarity with safety technology solutions including wearable gas sensors, proximity sensors, drones and robotics (Figure 10).

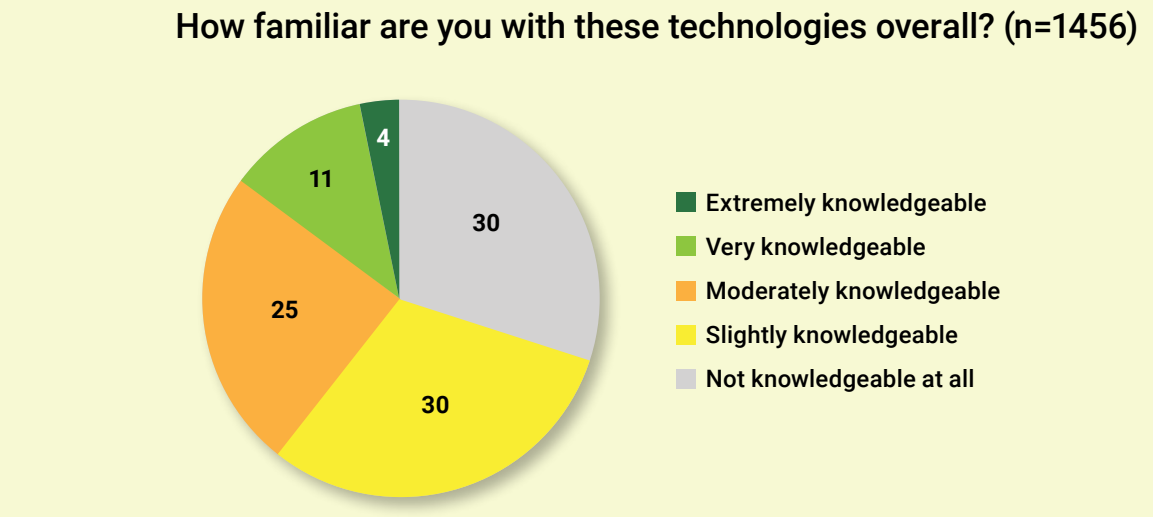

Figure 10. Pie chart illustrating the percentage of participants who responded about their familiarity with safety technology

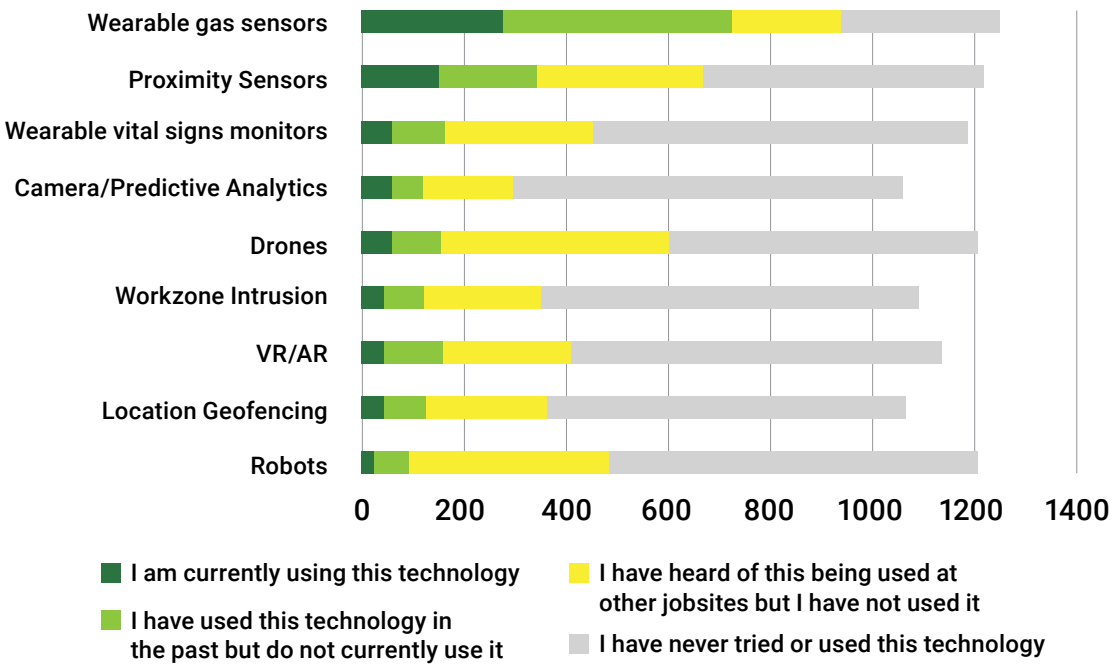

Figure 11. Counts of participants who responded about their use or awareness of specific safety technologies

Participants were also asked about what specific technologies they were currently using at their job sites, or if they had used them in the past or heard about them being used. Figure 11 illustrates these responses. Overall, the current use of technology is generally low. Depending on the specific device, only 27 to 282 participants reported currently using technology at their jobs. The most commonly used safety technology reported was wearable gas monitors. These monitors are used to detect combustible atmospheres, oxygen-deficient areas and toxic gases that may be present in a worker's environment. The monitors will alert workers to these hazardous environments and are often used for confined space entry in construction, utilities and agriculture. Of the 1,255 participants responding to this question, 728, or 58%, reported currently or previously using these devices. Likely, participants using these monitors were not using them specifically for crane operations but for other work on the job site.

The second most used technology was proximity sensors. These sensors can minimize risks related to vehicle-pedestrian interactions by detecting when equipment or vehicles get within a set proximity of the device and then alert workers. "Struck-by" and "caught-between" injuries are both part of the OSHA "Focus Four Hazards," which are priority topics for construction safety training (OSHA, 2023). Of the 1,223 participants who responded to the question about the use of proximity sensors, 157 participants (13%) reported currently using them, while an additional 191 (16%) reported having used them in the past. Twenty-six percent reported having heard of them being used at other job sites.

Those who reported currently or previously using proximity sensors were asked to provide feedback on the benefits and drawbacks of the technology through open-ended responses. The most frequently reported benefits included collision prevention ("sensors on crane booms to prevent collisions in blind lifts"), having warnings and alerts ("alerts operator when close to structures", "warns others of dangers that can be present") and mitigating blind spots ("help you know when there is someone behind you or in your blind spot"). Other benefits reported included the prevention of equipment and property damage and improving focus on the job. Some respondents specifically referred to using them around powerlines and using them to help maintain maximum and minimum boom angles on heavy lifts.

The most common drawbacks reported on proximity sensors had to do with worker dependency – even complacency – when using these devices. One participant wrote, "The drawbacks are that you start to rely more on those systems and become less aware of your surroundings." Other drawbacks included false alerts ("dirt, debris, bad weather [cause] false alerts and sensor issues") and alarm fatigue ("find we quickly start ignoring them if they are set too sensitive").

Participants also reported on the use of wearables for vital signs monitoring. These devices are often used to track heart rate and body temperature to ensure worker health and safety. They can be helpful for workers in high-heat environments who may be vulnerable to heat stress and dehydration. Only 166 participants reported currently or previously using these devices, which is approximately 14% of those who answered the question.

Approximately 25% of participants with experience using vital signs monitors reported that being able to monitor and track heart rate was beneficial to them. One participant said, "As an older member of the workforce, it is important for me to stay on top of stressors," and another mentioned it helped to understand their "response to changing conditions." Another said, "Heart rate monitors are almost essential at this point." Reported drawbacks included an invasion of privacy ("don't feel employer needs access to that kind of personal information") and others wrote about how wearables may increase risks in their work environments ("entanglement," "can get hung up on objects" and "added weight [and] heat").

Drones were used by a small percentage of participants (5% currently and 8% previously). Drones can be used to eliminate risks by keeping workers out of hazardous areas (i.e., confined space entry, work at height). Of the participants with experience using drones on the job site, one of the most frequently reported benefits was that drones kept workers safe: "can get a decent look at a piece of equipment or installed work to inspect it without putting someone at risk," "do crane inspections without the risk of falling" and "can accurately look at sites without the danger of climbing on buildings."

Besides keeping workers safe, another benefit common of drones in the responses was overall improved job site visualization. One participant said, "A bird's eye view gives a different and overall perspective of a job site and can help spot or predict possible job site interferences." Others stressed the importance of being "able to see a job site before starting work." Participants reported the drawbacks of using drones included them being a distraction ("distraction to other workers" and "another thing for an operator to dodge") and replacing the human perspective ("not the same as touching and seeing" and "takes away the hands-on aspect if you need to feel tension…or if you need to decipher between dirt/grease and a crack").

Regardless of their experience with technologies, participants were also asked about their perceptions of safety technology and how it could be used to promote safety within the crane industry. Overall, there was high general acceptance of technology across age groups and primary roles (Figure 12). Many responses to open-ended questions described a willingness to use any technology solution as long as it improved safety ("anything that enhances safety is beneficial," "anything that helps me feel safer, I'm all for it" and "anything to keep my men safe").

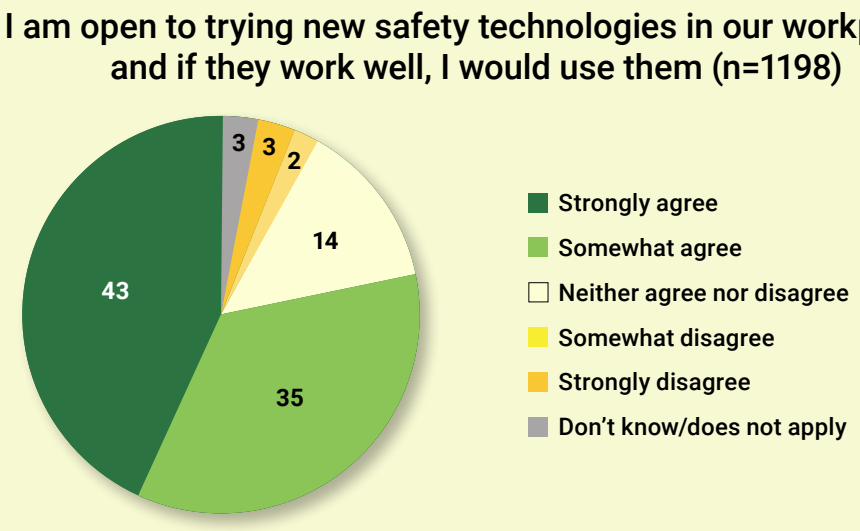

Figure 12. Pie chart illustrating the percentage of participants' level of agreement with the question regarding willingness to try new safety technologies.

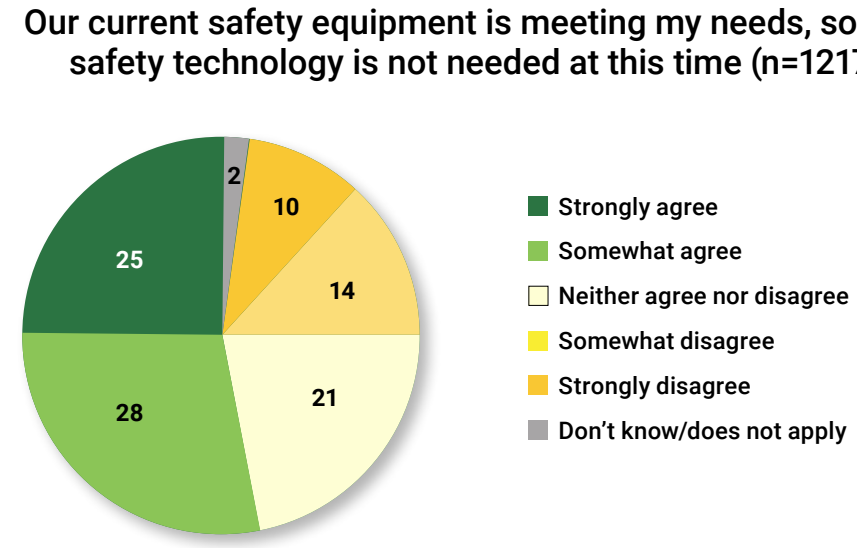

Figure 13. Pie chart illustrating the degree to which participants agree or disagree with this statement regarding the need for safety technology. Each section represents the percent of participants who responded.

Participants were also asked questions to understand the potential barriers and motivators to using safety technology. Responses shown in Figure 13 indicate a slight majority of participants (53%) do not believe new safety technology is needed because current safety equipment is meeting their needs. Less than 20% of participants believe the training required for new safety technology would be more trouble than it's worth and only 16% said they were not comfortable with new technology and were concerned it would be difficult to learn (Figure 14).

Further analysis of these responses indicated no substantial differences between age groups when it came to concerns over learning new technology. Between four and seven percent of respondents in each age group indicated they were concerned about technology being difficult to learn. Five percent of both those who held certifications for one to five years and those with over 15 and 20 years of certification agreed technology would be difficult to learn.

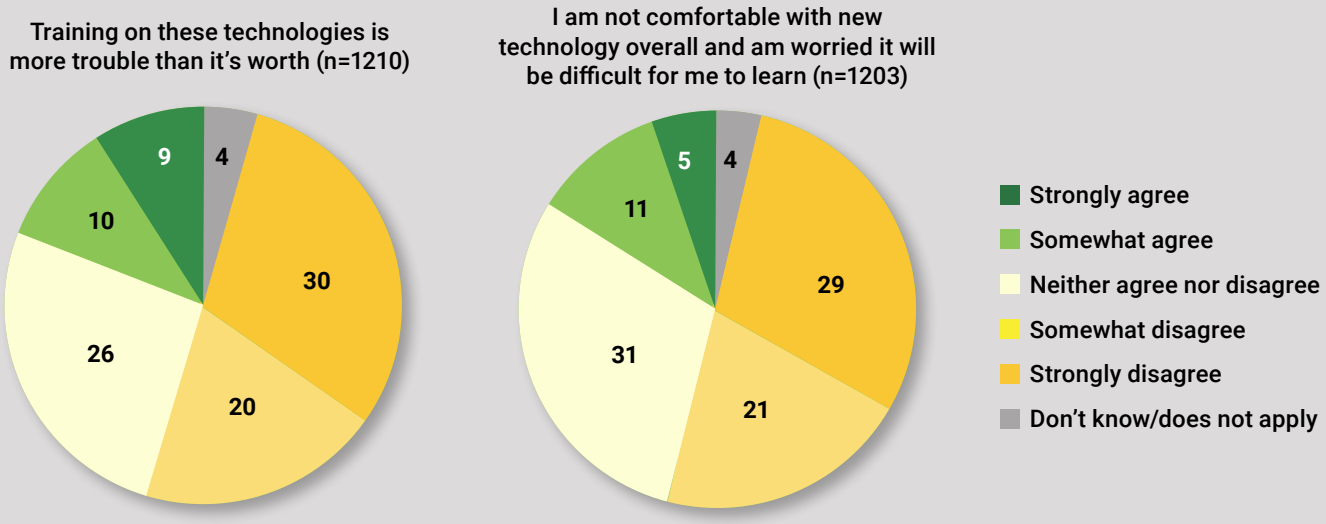

Figure 14. Pie charts illustrating the percentage of participants agreeing or disagreeing with statements about barriers to technology.

Participants were asked to rate their level of agreement with the statement, "The collection of my personal information (e.g., heart rate, body temperature) is a violation of my privacy" (Figure 15). This figure indicates close to 40% of participants are concerned with privacy issues and the collection of personal data.

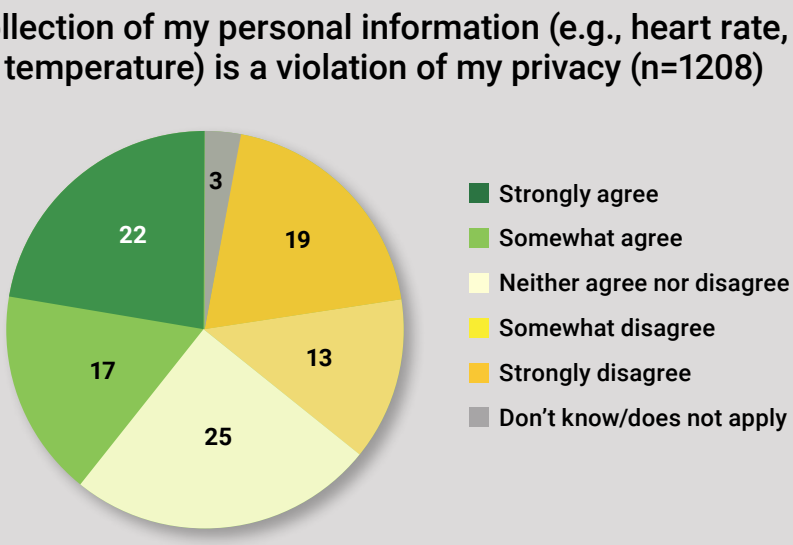

Figure 15. Pie chart illustrating participants' varying level of concern regarding personal data collection and privacy

Additional barriers to technology implementation were identified through open-ended responses. Participants pointed out some of their job sites restricted the use of electronics, including safety technology, due to the risk of explosion or fire, so any safety technology being used must be intrinsically safe if required. An additional concern identified as a theme in open-ended responses was the concern that overreliance on technology would lead to increased risks from worker complacency, alarm fatigue, or reduction in knowledge and skill. One participant described, "Unfortunately when we rely on too much technology, the skill and knowledge of workers tends to atrophy."

Other participants pointed out that despite alerts and notifications from technology solutions, there should still be workers present to assess safety and react in the event of an incident. One person described, "Technology is a good option but I still believe in the buddy system and there should never be just one person working by themselves when there is a potentially hazardous environment. There needs to be someone there as a safety watch." These responses emphasize a need for a human-centered approach to technology implementation, where workers can be involved in how and when technology solutions are deployed.

Limitations

As with any survey, the analysis is limited by self-reported data, which may be subject to bias. Participants were asked about the likelihood of exposure and the common contributors to injuries within the past two years. Since the survey was deployed in July, it is possible that participants were more aware of the risks associated with working in high-heat environments and therefore considered it a more likely exposure. Concern for hazardous heat is increasing across industries though, and in 2023, OSHA sponsored a program to raise awareness of heat exposure in workplaces.

Participants were allowed to skip questions if they chose to do so, which allowed response rates for each question to vary. Overall, there was a high response rate, and with the target population of approximately 100,000, the margin of error was approximately 3%. An additional limitation was the limited ability to see differences between groups. Because the participants were mostly operators (85%) in the construction industry (75%), and many had multiple certifications (58%), we were unable to compare exposures between industries and certification types. Additionally, since the sample sizes for primary roles other than operators were small (<150), those results may be less representative of their target populations.

Conclusions and Recommendations

To better understand the current state of safety hazards in the crane industry, NSC and the NCCCO Foundation partnered to deploy a survey of certified crane operators, riggers, signalpersons and inspectors. The survey identified certificants' most likely exposures, the top situational and systemic risks associated with injuries on the job, and their use and awareness of different safety technology solutions that can be used to mitigate risks associated with crane operation. Participants were also asked questions about safety policy and preparedness at their job sites and their format preferences for safety training.

Survey participants reported they were likely to be exposed to work at height (55%), vehicle-pedestrian interactions (64%), and loading and unloading activities (89%). In 2020, WTZ found these three hazardous situations accounted for a combined 30% of non-roadway occupational fatalities. Participants also reported the situational risks they were most likely to be exposed to as being struck by falling objects, equipment overturns, lightning strikes, contact with overhead powerlines, being struck by machinery or equipment (including the boom or jib), and falling from height. The two systemic risks that participants reported as their most likely exposures were heat stress and fatigue.

In addition to being asked about the likelihood of exposure, participants were also asked to identify which situational and systemic risks led to personal or on-site injuries in the last two years. The most common situational risks reported were fall from height, struck by falling objects, lightning strikes, being struck by equipment or by a vehicle, equipment overturn and crushing by equipment. The most common systemic risks reported were heat stress, fatigue, lack of training and being unfamiliar with the job site.

It is recommended that employers prioritize safety training and controls on the top risks that cause or contribute to crane operator injuries and the likelihood in which they believe they will be exposed. Figure 16 illustrates both the likelihood of being exposed to risks and the extent to which these risks were reported to have caused or contributed to injuries in the last two years. These charts may be beneficial in prioritizing safety training and interventions.

For example, heat stress is located in the top far right of the chart because it was the most common contributor to injuries and participants consider it their most likely exposure. It is recommended that employers and training providers take immediate action to control these hazards since they are both likely exposures and top contributors to injuries. Conversely, both permit-to-work failure and trench collapse were not considered likely exposures, nor were they reported as main contributors to on-site injuries. **It is important to note that this prioritization does not factor in the severity of outcomes, and there is still potential for these risks to occur, and potential they may result in serious injuries or fatalities.** Therefore, these risks should continue to be monitored and controlled.

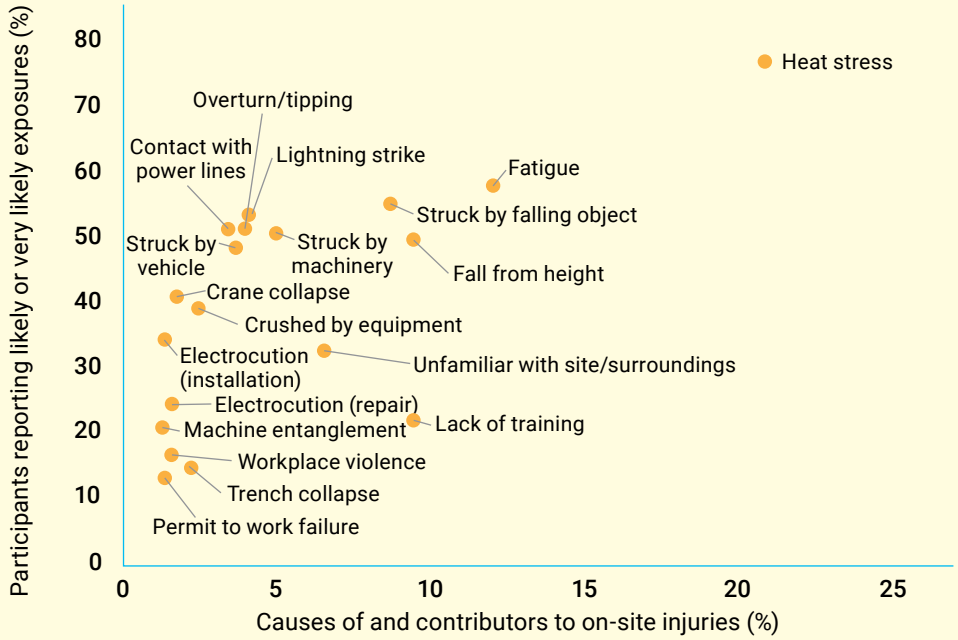

Figure 16. Chart illustrating the percent of participants reporting likely exposures to different situational and systemic risks compared to the percentage of those risks that contributed to on-site injuries in the last two years

Priority Recommendations

- **Heat stress:** Working in high-heat environments can lead to both serious injuries and illnesses. Heat stroke is a medical emergency and may be fatal. Symptoms of heat illness, such as dizziness and sweating may contribute to injuries (e.g., slips, trips, falls, dropping objects which may strike others). Job sites should develop heat stress prevention programs that include safety training on how to prevent and recognize the signs and symptoms of heat stress and illness. For more information on heat illness prevention, see OSHA's **website**. Potential technology solutions that may help mitigate these risks include wearables for vital signs monitoring. When using wearables, it is critical to engage workers throughout the implementation process and have clear data management policies in place.

- **Fatigue:** Fatigue can cause workers to have trouble focusing, remembering and concentrating. It can also increase distractibility and decrease muscle coordination. All of these symptoms can contribute to injuries. Safety training should include how to recognize the signs and symptoms of fatigue. Potential technology solutions that may help risks caused by fatigue include wearables for fatigue monitoring. When using wearables, it is critical to engage workers throughout the implementation process and have clear data management policies in place. For more information on fatigue monitoring and wearables, see the Work to Zero **website**.

- **Struck by falling objects and falls from height:** Both of these risks are associated with working at height. Safety training should include fall protection and how to properly use personal fall arrest systems if required for any assigned work. Drones may mitigate or even eliminate risks associated with working at height. Drones can be used for inspections or visualizations and eliminate the need for a worker to be off the ground. When implementing drones, it is critical to engage workers throughout the implementation process and provide additional training for drone operators. For more information on drones, see the Work to Zero **website**.

Recommendations to Monitor and Manage

Risks that appear in the bottom right portion of Figure 16 (i.e., lack of training, being unfamiliar with site/surroundings) were risks survey participants did not consider they would likely be exposed to but did contribute to a higher percentage of injuries than other risks in the left portion of the figure and should therefore be managed. This finding about concern over training aligns with survey responses indicating that more than 80% of respondents felt they had access to proper training before starting a task. It is not surprising then that it was not considered a likely exposure.

However, since injuries are still occurring, it could mean there is some bias present in the self-reported data and participants feel overconfident in their training. It is therefore critical to continue to offer safety training to crane operators and to provide on-site training to help familiarize workers with their job sites. Drones may also be a potential technology to help familiarize workers with new job sites. As noted in the survey responses, crane operators reported they were great for visualizations and identifying job site layouts and potential hazards.

Risks that appear in the top left portion of the chart were considered to be likely exposures even though they did not contribute to as many injuries as other risks. It is possible that these risks are being effectively controlled and thus not often leading to injuries. These risks should continue to be monitored and current training and controls should be continued. Lastly, employers and training providers should encourage near-miss reporting. Survey participants reported they were more likely to report injuries than near-misses. Tracking and understanding near-misses can help job sites understand potential causes of injuries and work to prevent injuries before they occur.

Next Steps

NSC and the NCCCO Foundation plan to continue this work and provide additional resources to educate crane operators, inspectors and employers about the hazards in the crane industry and technology solutions that may help eliminate or mitigate them. Future work will include case studies highlighting different technology solutions being used for crane operations to illustrate how these solutions are being used in the field and a report describing the crane industry in comparison to other industries.

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