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A STRATEGIC SAFETY-RISK MANAGEMENT PLAN FOR RECOVERY AFTER DISASTER OPERATIONS

Mohammad Sadra Fardhosseini,[1,3] Behzad Esmaeili,[1] and Richard Wood[2]
[1] Durham School of Architectural Engineering and Construction, University of Nebraska–Lincoln
[2] Civil Engineering Department, University of Nebraska–Lincoln
[3] sadra.fh@huskers.unl.edu.edu

Abstract: One of the early activities in any post-disaster management plan is to remove debris, clean the area, and reconstruct the damaged properties. However, a major focus of workers involved in cleaning operations after a disaster are concerned about construction safety because there are several unknown hazards that differ from hazards in a typical construction project. The risk can be compounded by the fact that construction activities after a disaster are usually conducted by small companies or even property owners with limited knowledge of safety. Therefore, the objective of this study was to develop a safety-risk management plan for recovery after disasters. The objective was achieved in two distinct phases. The first phase of the study focused on risk identification. An extensive literature review was conducted to identify hazards in post-disasters operations. The primary list of hazards was identified and classified into seven major groups: (1) physical; (2) chemical; (3) biological; (4) weather and temperature; (5) ergonomic (6) psychological; and (7) other (e.g., natural hazards and noise). During the second phase of the study, risk assessment was conducted to quantify the safety risk of the hazards identified in the previous phase. Fourteen safety professionals with an average 18 years of experience participated in the risk assessment. It was found that being caught-in/between a trench, getting electrocuted while using cranes or boomed vehicles near energized power lines, and getting electrocuted while using conductive tools, ladders, or scaffolds near energized power line are the hazards that cause the most severe injuries. Concurrently, working in cold or windy weather is the most frequent and risky hazard in post-disaster recovery operations. A risk matrix was developed for post-disaster operations by determining the likelihood and consequence of potential accidents using a 5-point Likert scale. It is expected that the results of this study will transform the current safety practices in post disaster recovery operations by providing an easy-to-use safety-risk management tool.

1 INTRODUCTION

On average, natural and man-made disasters cause approximately $24 USD billion worth of damage and affect the lives of 60 million people around the world (United Nations Human Settlements Programs, 2001). In the United States alone (1980-1999), thirteen hurricanes caused $68 billion in damages and more than 400 deaths (National Oceanic and Atmospheric Administration, 2000). Recently, in January 2010, the Haiti earthquake ruined around 250,000 houses (Arumala, 2012). To cope with such a huge loss, a large number of studies have been conducted to develop emergency response plans (Perry and Lindell, 2003; Sheu, 2007), revise land-use regulations (Burby and Dalton, 1994), improve building retrofitting programs (Erdik and Durukal, 2008; Rey, 2004), or design more effective early warning systems (Hooke, 2000; Zschau and Küppers, 2003).

Natural disasters, such as hurricanes and floods, cause severe damage and demand infrastructural recovery, operations that typically involve construction workers. The number of workers who are involved in post-disaster recovery and reconstruction depends on the scale of the catastrophe; however, this number can reach up to 18,000 workers (Rotimi et al., 2006). Workers involved in cleaning and reconstruction operations after a disaster face greater danger than traditional workers because they are exposed to chemical-biological materials, contaminated floodwater, downed energized power lines, confined space entry, potential structural collapse, or other high-risk situations. For this reason, careful attention should be paid to identifying and assessing potential safety risks for these workers. Unfortunately, there are currently a limited number of studies that investigate the potential hazards for workers involved in post-disaster operations.

To address this limitation in the body of knowledge, the overarching goal of the broader project is to enhance the safety of workers in post-disaster recovery and reconstruction operations. Within this large-scale project, our objectives are to: (1) identify common hazards in post-disaster recovery and reconstruction operations; and (2) quantify the safety risk of common hazards in post-disaster recovery and reconstruction. The results of the study will help practitioners to create more effective training programs for workers involved in post-disaster recovery operations.

2 LITERATURE REVIEW

In one of the seminal studies, Esworthy et al. (2005) published a report through the Congressional Research Service (CRS) Reports about the environmental considerations for cleanup activities after hurricane Katrina. This report includes a comprehensive review of activities that were carried out during the cleanup process. These activities included—but were not limited to—debris assessment and management, oil and other hazardous materials' evaluation; the evaluation of previous contaminated sites; dewatering; cleaning up water; recycling, reusing or disposing of the debris; and monitoring. This report provides a unique insight into the difference between the common hazards in ordinary construction projects and cleanup response in recovery after a disaster.

According to Esworthy et al. (2005), one of the major differences between a post-disaster recovery operations and ordinary construction projects is that a natural or man-made disaster can cause large amount of debris. For example, the amount of debris created by Hurricane Katrina was estimated at 55 million cubic yards (Esworthy et al., 2005). The debris consisted of construction materials, damaged or destroyed building fragments, sediments, green waste (trees, limbs, leaves, and shrubs), white goods (utensils), asphalt, oil, chemicals, and other substances. To conduct an efficient debris management program, one needs to accumulate all debris and separate the hazardous materials from other substances. During these operations, construction workers are exposed to hazardous materials, such as pesticides, drain cleaners, cleaning supplies, paint, asbestos, and surfaces coated in lead-based paint.

Another early recovery after disaster activity is to remove the trapped water. For example, after Hurricane Katrina, 114 million gallons water had to be pumped out from the city of New Orleans (Esworthy et al., 2005). The difficulties of such an operation can be compounded by the fact that the water was contaminated with animal and human sewage, decaying bodies, oil, gas, and other chemicals. If water contains bacteria and poisonous metals (e.g., arsenic), then the area can be exposed to epidemic and contagious diseases. Even after draining the water, some pollutants can remain in the sediments, and the mixed water evaporation or the released chemical substances can affect the air quality of the disaster area. In addition, in such an unfavorable situation, the presence of rodents, insects, and the growth of fungi and molds (e.g., humid conditions) can also contaminate the area.

In another study, Reissman et al. (2008) studied emergency responders' safety and health after a disaster by focusing on the situation of people involved in the September 11th World Trade Center disaster. The authors analyzed the emergency responders' time of arrival and the duration of exposure to dust. The authors found that due to the combustion, people in the area inhaled a lot of toxic fumes, and many people got injured by rubble when the buildings collapsed. It was concluded that disaster preparation activities should provide training regarding hazard identification, quick and effective scene control, personal tracking, and safety enforcement.

According to the literature, another common hazard in recovery after a disaster includes psychological disorders. These kinds of hazards are different from the ones in ordinary construction activities. In one of the studies, Kowalski et al. (2001) conducted research to enhance occupational health and safety of workers involved in emergency response. The authors found that work related stress can increase risk of injuries or psychological disorders. Various kind of stress, such as physical (bio-organic) and emotional (psycho-social) can cause fatigue, emotional withdrawal, and depersonalization. The authors stated that by obtaining knowledge of social science, safety managers might decrease the risk of work stress among workers. In another study, Reissman et al. (2008) found that disasters can increase the chance of psychological disease such as depression, panic disorder, and anxiety among workers. Working in high-stress environments in conjunction with viewing distressing scenes—i.e., those that include injuries and dead bodies—are factors for stress and other adverse psychological impacts (Benedek et al., 2007). Thus, to protect workers, this type of hazards should be taken into consideration as well.

Some researchers stated that assessment of a situation after a disaster using various data collection techniques can be helpful for reducing the risk of injuries. For example, to help first responders and civil engineers, Peña-Mora et al. (2012) developed a mobile workstation chariot (MWC) to conduct damage evaluation and hazard identification after a disaster. The workstation has a platform that provides mobility for people engaged in a disaster response and helps them collect, analyze, and distribute information to facilitate decision making. In another study, Gong (2013) suggested the use of mobile LiDAR to collect and analyze data for post-disaster recovery operations. The authors used this technique after Hurricane Sandy in the east coast and found that mobile LiDAR can outperform airborne remote sensing and typical ground survey data collection. While these innovative approaches can be used to enhance the situational awareness of workers involved in recovery after disaster operations, the current adoption rate of these innovations in actual construction operations is minimal. Therefore, there is a need to develop a practical way to identify hazards and assess their risk in post-disaster construction activities.

3 RESEARCH METHODS

The objective of the study was achieved by conducting two distinct tasks: (a) cataloging the common hazards in recovery after disaster operations; and (b) assessing the risks of the identified hazards. Prior to risk assessment, it was necessary to create a list of potential hazards in recovery after disasters for construction workers. Therefore, the first activity involved conducting a literature review to identify hazardous scenarios that lead to injuries in post-disaster recovery. Search engines such as the American Society of Civil Engineering (ASCE), Google Scholar, and Science Direct were used to find articles on these scenarios. A large number of studies have been conducted on post-disaster operations; however, studies on the safety risk of workers are limited. Therefore, to provide a comprehensive list of hazards, we also searched national databases such as those for the Occupational Safety and Health Administration (OSHA), Federal Emergency Management Agency (FEMA), and National Institute for Occupational Safety and Health (Niosh). These activities led to a list of common hazardous scenarios in post-disaster recovery and reconstruction operations.

The second activity served to quantify the safety risks associated with the common hazards identified in the previous task. We followed the traditional paradigm in risk quantification used in previous studies (Brauer, 1994; Hallowell et al., 2011; and Esmaeili and Hallowell, 2013) to obtain ratings of frequency and severity from industry experts. Since there is not enough archival data to make statistically significant inferences (Shapira and Lyachin, 2009; Rozenfeld et al., 2010) and since empirical data cannot be obtained in a realistic timeframe, to accomplish this activity, subjective risk-assessment techniques were employed. Accordingly, to quantify the safety risk of common hazards in post-disaster recovery and reconstruction projects, experts were asked to provide frequencies and severity of injury for each hazardous situation using five-point Likert scale. In this non-comparative scale, respondents were supposed to select a numeral value describes frequency and severity of each hazardous situation (Allen and Seaman, 2007; Jamieson, 2004).

To collect data, the questionnaire was distributed among safety professionals in the Midwest. Local contractors located in Lincoln and Omaha (Nebraska) were the main point of contacts. Other organizations such as the Nebraska Department of Roads (NDOR), the Midwest chapters of the Associated Builders and Contractors (ABC) and the Associated General Contractors of America (AGC) were also contacted. A copy of the questionnaire was sent to the safety managers of these organizations and encouraged them to distribute the questionnaire among people who might be able to fill it out. The research team also used their personal contacts with safety professionals to further increase the number of participants.

4 RESULTS AND ANALYSIS

As mentioned earlier, the first objective of the study was to identify common hazards in post-disaster recovery and reconstruction operations. This objective was achieved by conducting a comprehensive literature review on the current body of knowledge. In total, 45 hazards were identified and categorized into seven major groups (Table 1): (1) physical; (2) chemical; (3) biological; (4) weather and temperature; (5) ergonomic; (6) psychological; and (7) other (e.g., natural hazards and noise). The second phase of the study involved assessing safety risks associated with post-disaster recovery hazards. To accomplish this objective, we contacted 87 professionals and in total, 14 safety professionals returned the filled-out questionnaire. The people who returned the questionnaire were very well-qualified and had an average of 18 years of safety experience. Participants were mainly from the Midwest: 12 from the State of Nebraska, one from the state of Iowa, and one from the State of Illinois. The frequency and severity values for each hazard were independently quantified on a Likert scale and the results are shown in Table 1. To measure the internal reliability of data collected, Cronbach alpha was calculated for the frequency (0.984) and severity (0.992) scores reported in Table 1 that indicate excellent internal reliability.

Table 1: Median of frequency, severity, and risk factors obtained from safety managers

		Hazards	Frequency (Median) *	Severity (Median) **	Risk (S×F)
Physical	1	Falling from a ladder	2	3	6
	2	Falling from an unprotected edge, opening, or skylight	1	4	4
	3	Falling from a scaffold	2	3.5	7
	4	Falling from a structural frame (tower, steel frame, …)	2	4	8
	5	Falling from an aerial platform	1	4	4
	6	Struck-by a boomed vehicle	1	3.5	3.5
	7	Struck-by construction equipment	1.5	4	6
	8	Struck-by nail gun	1	2.5	2.5
	9	Struck-by personal vehicle	2	4	8
	10	Struck-by flying debris/objects	2.5	3	7.5
	11	Struck-by falling objects	2	3	6
	12	Caught-in/between a trench	1	4.5	4.5
	13	Electrocuted while using cranes or boomed vehicles near energized power line	1	4.5	4.5
	14	Electrocuted while using conductive materials, ladder, or scaffold, near energized power line	1	4.5	4.5
	15	Electrocuted while working on/near live wiring or energized circuit	1	5	5
	16	Electrocuted while working with electrical device, tool	1	4	4
	17	Electrocuted after contact with underground, buried power lines	1.5	4	6

* 1=0.5; 2= 1.5; 3=2.5; 4=3.5; 5=4.5.

** 1= 0.5 2=1.5; 3=2.5; 4=3.5; 5=4.5.

Table 1 (continued): Median of frequency, severity, and risk factors obtained from safety managers

		Hazards	Frequency (Median) *	Severity (Median) **	Risk (S×F)
Chemical	18	Entering a confined place that has the probability of toxic gas emission	1	3.5	3.5
	19	Touching paints and plastics materials that can cause Asthma	1.5	3	4.5
	20	Demolition, plumbing, or painting that exposes workers to lead	1	3	3
	21	Exposure to metal materials coating and metal clearing	1	2.5	2.5
	22	Exposure to rust-preventing on steel	1.5	2.5	3.75
	23	Inhaling fumes during welding and cutting (galvanized metal, alloy, and brass)	3	3	9
	24	Demolition, dry wall installation, enhancing fire-proofing, and insulation activities that expose workers to asbestos	1	2.5	2.5
	25	Stone dressing, masons quarry, and stone cutting	1	2	2
	26	Inhaling cement particles while making concrete, which can cause lung cancer, chest pain, and difficulty in breathing	2	3	6
	27	Working with MDF in demolition and sawing, which can cause coughing, wheezing, or stomach pain	1.5	2.5	3.75
Biological	28	Exposure to fungi, mildews, yeasts, and mold	2	3	6
	29	Encountering corpses of people and animals during rescue operations	2	2.5	5
	30	Touching poisonous plants or inhaling the fumes that result from burning such poisonous plants	2	2	4
	31	Exposure to disease, such as Hepatitis, Tuberculosis, Tetanus, Legionella and Rabies	2	3	6
	32	Exposed to sludge and debris	2	2	4
Weather	33	Working in a hot and humid outdoor condition for a long time	4	3.5	14
	34	Working in a hot indoor room without suitable ventilation	2	2.5	5
	35	Working in cold or windy weather	4.5	4	18
Ergonomic	36	Lifting heavy weight in adverse positions	3	3	9
	37	Using excessive force (over-exertion)	2	3	6
	38	Using unsuitable devises for a specific job	2	2.5	5
	39	Griping a part of the body during the task	2	2	4
	40	Performing an activity frequently	4	3	12
Psychological	41	Substantial distress responses (e.g., sleep disturbance, fear, and worry-altered connections)	2	3	6
	42	Mental health and illness (e.g., post-traumatic stress disorder (PTSD), acute stress disorder (ASD), and depression)	2	3	6
	43	Behavioral changes in high-stress environment (e.g., smoking, evacuation, alcohol, and over-dedication)	2	3	6
Other	44	Encountering natural hazards (exposure to snakes, wasps & bees, spiders, scorpions, and mosquitoes)	3.5	3	10.5
	45	Exposure to disturbing noises	3.5	3	10.5

* 1=0.5; 2= 1.5; 3=2.5; 4=3.5; 5=4.5.
** 1= 0.5 2=1.5; 3=2.5; 4=3.5; 5=4.5.

4.1 Physical Hazards

Physical hazards include falls, struck-by, caught in/between, and electrocution hazards. These hazards are usually referred to as “the big four” because they are responsible for almost 60% of all injuries in the construction industry (OSHA Training Institute, 2011). In total, 17 different physical hazards were identified and included in the survey (Table 1). One of the interesting findings of the study is that, based on the safety managers’ judgment, in recovery after disasters operations physical hazards do not occur as frequent as ordinary construction activities. The highest frequency belongs to the “struck-by flying debris/objects.” On the other hand, physical risk have some of the most sever hazards.

According to the ratings provided by experts, struck-by flying objects is considered to be the most critical hazard in this category. Both the severity and frequency of this hazard were rated as 3. In addition, falling from structural frames, electrocution after contact with underground power lines, and struck-by personal vehicle were placed as the second and third most risky hazards. Furthermore, caught in/between a trench and electrocution from various sources were highlighted to have the worst consequences.

4.2 Chemical

Hazardous chemical substances are one of the potential safety risks that construction workers face when involved in debris-removal after a disaster. Although, we expected to see chemical materials as a frequent hazard in recovery after disaster operations, the experts who participated in the study rated this hazard with frequency ratings of one or two (Table 1). Inhaling welding fumes is found to be the most perilous hazard in this category and the highest severity belongs to entering confined places. Wearing suitable respiratory protection, work and rubber gloves, steel toe boots, outer clothing, and other PPE are the most common suggested approaches that can reduce the severity of chemical hazards (Grosskopf, 2010; OSHA 29 CFR, 1926; Health Hazards Workbook, 2012).

4.3 Biological

During rescue operations, unwatering, and cleaning up debris activities, workers are prone to various biological hazards. Allergies, dermatitis, asthma, and lung disease are the most common outcomes of exposure to biological hazards (Esworthy, 2006; Grosskopf, 2010). The results of the survey indicated that the range of risks for most biological hazards is between 4 and 6, and the safety managers do not consider them as fatal risks during recovery operations. Wearing protective clothing, respiratory devices, and proper gloves in conjunction with immunization (vaccination), carrying both insect repellant and first aid devices are the most recommended mitigation plans against this type of hazard (Grosskop, 2010; Health Hazards Workbook, 2012).

4.4 Weather

Working under extreme weather conditions can be hazardous for the workers. For example, if workers are exposed to extreme sun, their skin might suffer from sunburn. In extreme conditions, exposure to sun can even cause skin cancer (melanoma). Experts identify this type of hazard to be the most frequent and severe hazard of all the selected conditions (Table 1). Temperature and weather effects are some of the most risky hazards identified in this study. Working for a prolonged time in adverse weather might cause problems such as frostbite, hypothermia, heat cramps, heat exhaustion, heat rashes, and heat stroke for the workers (Health Hazards Workbook, 2012). Some mitigation strategies are suggested below.

When the weather is extremely hot, several actions should be taken to protect workers: workers should eat small portions; they should not drink caffeinates beverages or alcohol; cool liquids should be provided for workers; frequent breaks should be allowed; and workers should be encouraged to wear cotton and proper clothes (Health Hazards Workbook, 2012). Working in an extreme cold weather (below - 32°C) can also be hazardous for workers. This condition can be exacerbated when the weather is wet and windy (Health Hazards Workbook, 2012). Wearing proper clothing and carrying relevant PPE are proper actions against cold weather. In addition, workers should put on dry clothes, drink a lot of warm beverages, take a break at regular intervals, and report any weird symptoms to the supervisor (Centers for Disease Control and Prevention, 2015).

4.5 Ergonomic hazards

Ergonomic hazards are defined as the possible incidents that might happen due to a poor relationship between work features and the mental and physical abilities of the employees (Faridah et al., 2008). Some of the most common ergonomic hazards are strains and sprains, fatigue, carpal tunnel syndrome (vibration), low back pain, and tendonitis (OSHA Publication 3125, 2000). Both the risk and consequence of performing an activity frequently (fatigue) is at the top of the ergonomic category (Table 1). The results of the study indicate that fatigue plays a significant role in potential injuries after a disaster. Removing debris from an exposed area requires extensive material handling and physical activity. Following measures can help the workers to reduce the ergonomic hazards (Ramsey et al., 2014): reducing the distance between the load and the body; avoiding excessive twisting; traversing with the load for fewer than 10 feet or using a conveyer; using proper personal protective equipment; having enough training (e.g., lifting techniques); taking breaks; wearing robust resistance gloves; and using pneumatic and power tools.

4.6 Psychological

The construction workers are one of the first people who will arrive in an area that has been hit by a disaster and will be exposed to numerous psychological hazards. Working in high-stress environments, such as recovery after disasters, can lead to post-traumatic stress disorder (PTSD) among workers. The symptoms of PTSD can be initiated by observing unpleasant experiences, such as seeing others' injuries, suffering personal injuries, losing loved ones, or encountering dead bodies. Headaches, loss of asleep, nervousness, and nightmares are some the symptoms of people impacted by PTSD (Benedek et al., 2007).

The results of the survey demonstrated that psychological hazards threat workers approximately as often as chemical and biological hazards in post-disaster recovery and reconstruction (Table 1). Thus, these hazards should be taken more seriously. The risks of post-traumatic stress disorder, behavioral changes, and substantial distress in a recovery after a disaster operation have been designated as a 6 for all. Previous studies stated that improving social science can mitigate the consequences of psychological disorders (Benedek et al., 2007). To control for psychological hazards, periodic medical treatment, counselling service, training programs (e.g., relaxation, medication and biofeedback), and providing recreation activates can be helpful (World Health Organization, 2001).

4.7 Other hazards

Noise and natural hazards were viewed as moderate risks (Table 1). Every year many construction workers suffer from noise in construction sites. Due to the chaos conditions in post disaster environments, workers might suffer from noise hazards as well. Therefore, using hearing protection devices, performing supervisor's controls in conjunction with restricting workers' proximity to the damaging noise hazards areas can be enumerated as the most effective approaches used to reduce noise hazards (Health Hazards Workbook, 2012; Bergström and Strom, 1986; Franks et al., 1996).

After a disaster, due to the moist conditions, deficient hygiene, and prevalence of animal corpses; a large number of rodents might surge into exposed areas. Increasing rabies aside, the presence of rodents make their hunters (snakes, scorpions, and spiders) follow them into the regions. Therefore, a careful attention should be paid to natural hazards. Finally, wearing proper pants, boots, gloves, and outer clothing will help workers to keep themselves safe during operations (Health Hazards Workbook, 2012).

To provide a visual representation, the findings are summarized in a risk matrix (Figure 1). As it is clear that weather-related hazards are the most critical safety risk-factors in post-disaster recovery operations. Several mitigation practices are suggested in this paper to help practitioners reduce the risk of injuries for workers involved in recovery after disaster operations.

Risk Assessment			Frequency				
			highly unlikely	unlikely	likely	highly likely	Near certainly
			1	2	3	4	5
Severity	Fatality	5	PHY (12, 13,14,15) [5]	10	15	20	25
	Major injuries	4	Phy(2,5,6,16), Chem (18) [4]	Phy (3,4,7,9,17) [8]	12	Weather (33) 16	Weather (35) 20
	Moderate injeries	3	Phy (8), Chem (20,21,24) [3]	Phy (1,11), Cehm (19,22,26,27), Bio (28,29,31), Erg (37,38), Weather (34) Psy(41,42,43) [6]	Phy (10), Chem (23), Erg (36) [9]	Other (44,45), Erg (40) [12]	15
	Minor injuries	2	Chem (25) [2]	Bio (30,32) Erg(39) [4]	6	8	10
	Trivial injuries	1	1	2	3	4	5

RED: Extremly risky. Emergency attention is required

Yellow: Hazardous. This risks should be taken into the consideration

Green: Negligence risks. Minimum action is needed for prevention

Figure1: Risk matrix - The medians of frequency and severity have been rounded up.

5 CONCLUSION

After a disaster, workers who are involved in recovery and maintenance activities are exposed to large number of hazards that are not similar to hazards related to typical construction activities (Faridah et al., 2008). Protecting workers from hazards during recovery after disasters is gaining attention in both academia and practice (Esmaeili et al., 2014). To address this emergent need, this study sought to identify common hazards in post-disaster recovery operations and to assess their safety risk in terms of frequency and severity. Practitioners can use findings of the study to identify high risk situations in post-disasters recovery operations and implement mitigation plans to reduce potential of injuries.

In future stages of this research project, we aim to develop a safety guideline for workers involved in recovery after disaster operations. The guideline will summarize best mitigation practices for dealing with safety risks in construction operations after a disaster. Furthermore, to disseminate the results of the study and reach a larger audience, a mobile application will be developed. Nevertheless, the findings reported in this paper will advance the subsequent tasks of our overall project in the years to come.

There are some limitations related to this research that need to be addressed in future studies. First, the frequency and severity rating were obtained from safety managers mainly located in Nebraska. This situation will limit the external validity of the study. Future studies should be conducted to collect data from larger and more diverse groups of experts. Second, assessing the frequency and severity of hazards using a Likert scale does not provide an accurate estimate of actual risk in sites. Further studies should be conducted to measure the safety risk of identified hazards more accurately. Despite these limitations, the study provides a significant contribution to the practice by helping safety managers to identify and strategically manage safety risks in post-disaster recovery operations.

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