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Assessing on-site construction personnel hazard perception in a Middle Eastern developing country: An interactive graphical approach

Mohamad Abbas, Bahaa Eddine Mneymneh, Hiam Khoury*

Department of Civil and Environmental Engineering, American University of Beirut, Lebanon

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ABSTRACT

The construction industry is unarguably one of the most dangerous industries contributing to a high percentage of work-related injuries and fatalities. Despite various attempts at ensuring compliance with health and safety regulations and maintaining a safe working environment, the construction personnel attitude on jobsites remains one of the direct reasons behind reducing accidents. Therefore, assessing the hazard perception of the construction workforce is a substantial step in enhancing on-site safety management, especially in developing countries where construction safety is still at its infancy. In Lebanon, a Middle Eastern developing country, the construction industry has been characterized by an overall poor safety performance. Hence, the objective of this paper is to assess the awareness and perception of engineers, foremen and workers on the severity of various indoor hazardous activities and the importance of hardhat use through conducting a computer-based graphical interactive survey on different construction sites in Lebanon. Results revealed: (1) deficiencies in hazard perception among construction personnel, varying according to SHMS adoption by contractors, site characteristics, years of experience, and job position as well as (2) how the main incentive behind wearing a hardhat is actually having faced past incidents in lieu of self-motivation. The study findings together with recommendations issued for enhancing on-site construction personnel hazard and safety perception could be of significance to other regional developing countries.

1. Introduction

Construction is one of the riskiest industries worldwide (Guo and Yiu, 2015; Mneymneh et al., 2016; Abbas et al., 2016, Mneymneh et al., 2017). Despite the remarkable improvement of construction safety and health management that followed the Occupational Safety and Health Act (OSHA) of 1970 and the implementation of numerous safety measures, a sizeable number of construction works related injuries are still being reported (Huang and Hinze, 2006; Hallowell and Gambatese, 2009; Zou and Zhang, 2009; Kim et al., 2016). In 2014, the construction sector was responsible for 899 fatal injuries in the United States, second only to the trade and transportation sector with 1246 fatal injuries while the mining sector caused 183 (United States Department of Labor (2014)). According to the Health and Safety Executive (HSE, 2016), 66,000 non-fatal onsite injuries have been self-reported in 2015/2016 in the United Kingdom. The main causes of these injuries included being struck by objects or exposed to hazardous areas (Teizer et al., 2009).

As such, developed countries have invested remarkable efforts to enhance construction safety management and produce safety policies aiming to reduce work-related injuries. On the contrary, developing countries present weak commitment to construction safety. In Lebanon, a Middle Eastern developing country, a construction labor safety law exists but its enforcement is absent (Awwad et al., 2015). As a result, the Lebanese construction industry has been witnessing a large number of work-related injuries, with the highest percentage coming from the age category 20–29 (Nuwayhid et al., 2003). Despite the high levels of accidents, there have been no efforts targeted at studying and assessing on-site workforce awareness vis-à-vis hazardous activities and hardhat use in the Lebanese construction industry. This paper is the first to evaluate the construction personnel perception of hazards and safety in Lebanon by means of a computer-based interactive graphical survey rather than traditional questionnaires. Furthermore, the paper concludes by devising recommendations and improvement channels to enhance perception of potential hazards and importance of hardhat use which may be of great use to other developing countries in the region.

2. Background

The assessment of construction safety performance and practices is a

* Corresponding author at: Department of Civil and Environmental Engineering, American University of Beirut, P.O. Box 11-0236, Riad El Solh, Beirut 1107 2020, Lebanon.
E-mail address: hiam.khoury@aub.edu.lb (H. Khoury).

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fundamental part of safety management systems and has attracted the attention of many researchers (Sgourou et al., 2010, Shin et al., 2014; Wu et al., 2015). For instance, in the United States, the construction industry has been displaying higher rates of work-related injuries and fatalities than any other industry in the U.S (Huang and Hinze, 2006), mainly due to the use of heavy machinery and work under unfavorable conditions (Hallowell and Gambatese, 2009). The same applies to China and Australia (Zou and Zhang, 2009). As such, efforts have been channeled in the last years to devise extensive safety standards aiming at zero injury policies. As for the United Kingdom, Sherrat et al. (2013) assessed the status of safety on construction sites and indicated that, in addition to strict safety regulations and requirements such as European and UK laws, safety management systems are typically driven by high levels of safety culture and appreciation. Large contractors in the country were looking to engage with workers to improve cooperation and consciousness on construction sites. In other words, the study highlighted the shift in safety management policies from enforcement to engagement. On the other hand, as opposed to the aforementioned developed countries, developing countries have been displaying poor construction safety performance and evaluation (Bibb and Bust, 2006, Teo Ai Lin et al., 2008). Al-Humaidi and Tan (2010) stated that the construction industry accounts for over a third of the total work-related injuries in Kuwait. They evaluated recent accidents on different sites and concluded that the Kuwaiti construction sector is in a pressing need for improving safety regulations. Alkilani et al. (2013) collected data about the health and safety practices in Jordan, using field visits, discussions with construction personnel and semi-structured interviews and highlighted the main constraints hindering the proper implementation of health and safety rules. Raheem et al. (2016) worked on improving the existing safety situation of the Pakistani construction industry by proposing a framework that enhances the implementation of safety practices, and consequently joins the safety-related perceptual gaps between the stakeholders and regulatory authorities. Generally, studies suggested that underdeveloped regions still present inefficient safety records tracking, inadequate safety laws and regulations, lack of commitment and cooperation from clients and managers towards a healthy construction environment, and low levels of worker competence and safety training (Irumba, 2014, Chiocha et al., 2011). This applies as well to Lebanon, a developing country in the Middle East region. As a matter of fact, Awwad et al. (2015) was a first attempt at evaluating the construction safety practices in Lebanon. The study gathered data by conducting surveys and one-one interviews with different concerned parties including contractors, consultants, owners, insurance companies and governmental authorities. The results of this study showed weak commitment of construction stakeholders to safety practices, absence of enforcement of safety regulations, and poor safety education in the Lebanese construction industry. Nonetheless, this latter study did not include the perspective of on-site construction personnel other than project managers and safety officers on hazards and safety-related matters.

However, the on-site construction personnel perception of hazards remains one of the most crucial components of hazard exposure control and injury reduction on construction sites and has been the focus of many research efforts (Haslam et al., 2005, Carter and Smith, 2006; Hsu et al., 2012; Feng et al., 2014; Yu et al., 2014; Albert et al., 2014; Jeelani et al., 2017). As such, the impact of several factors on hazard perception has been studied. These include but are not limited to: job position, years of work experience, adoption of a safety and health management system (SHMS), site characteristics, etc. For instance, the impact of the job position on hazard and safety perception has been studied in various industries. Hallowel (2010) surveyed 22 different companies in the Pacific Northwest of the United States and interviewed 83 construction-related personnel in half-hour sessions, in order to assess the levels of safety hazards understanding and detect potential discrepancies between workers and managers. Results indicated high levels of perceived risk compared to tolerable risk values and the presence of a notable difference between the risk acceptance levels of workers and managers. Similarly, Chen et al. (2012) assessed the difference between perceptions of management and labor regarding construction safety practices. Results revealed that management is more aware than labor of construction site safety. Furthermore, in a recent study by Perlman et al. (2014), it was found that superintendents assessed the level of risk higher than students with little work experience and safety managers identified far more hazards than superintendent or student groups.

On the other hand, the impact of the years of work experience factor on hazard perception has been studied as well in several industries. For instance, Crundall et al. (2012) exposed drivers from different levels of experience to a series of hazards using a car simulator, with the aim to assess their hazard perception. Results showed that drivers with higher levels of experience were able to identify hazardous situations in a fast and more effective way. Similarly, in a study by Li et al. (2014) on situational awareness of first responders, results showed that the years of experience was the most impactful factor. The study suggested that requirements of first responders might change as their experience grew over time. Other research efforts investigated the ability of new entrants to the mining industry to recognize work-related hazards from several images of their work areas. It was found that the years of experience and age of the test subjects had an important effect on the workers' ability to identify hazards (Bahn 2013a). However, in the construction industry, a study by Perlman et al. (2014) suggested that the ability of superintendents to identify hazards is not positively correlated with their work experience in years.

Furthermore, the impact of adopting several characteristics of a SHMS (i.e. safety training, personal protective equipment (PPE) provision, presence of safety officers, etc.) on hazard and safety perception has been also studied in various industries. In the mining industry, for example, a study identified the importance of training, communication and documentation in enhancing hazard identification skills (Bahn 2012a; Bahn 2012b). Other prior research in the field of construction has generally attributed poor hazard recognition performance to ineffective training practices and shortcomings with traditional methods (Wilkins 2011, Perlman et al. 2014). The study conducted by Perlman et al. (2014) has stated, in particular, that formal, effective, and engaging safety trainings, safety directors and most importantly the constant presence of superintendents on site might play an essential role and highly influence the ability and performance of workers. In another study by Ulubeyli et al. (2014), a questionnaire survey was carried out with contractors and workers employed in several construction projects in Turkey. Results revealed that contractors overlooked safety training and were reluctant to invest in PPE whereas workers did not attach adequate importance to occupational training and safety.

Other studies have assessed the impact of site characteristics on hazard perception. According to Mitropoulos et al. (2005), the dynamic nature of construction projects makes it challenging for workers to visualize and predict tasks and hazards associated with it. Additionally, studies by Carter and Smith (2006) and Albert et al. (2013) stated that a large fraction of construction hazards remain unrecognized regardless of project type and project location. This is further confirmed in a recent study by Jeelani et al. (2017) that mentioned that workers may not possess complete knowledge on what hazards to expect and look for due to the presence of uncertainty and diversity across projects and situations.

On another hand, many studies have shown that psychological factors such as workload, organizational relationships, mental stress, job security, job satisfaction, supervision role and motivation, etc. can impact the perception and attitude of on-site construction personnel (Solís-Carcaño and Franco-Poot, 2014, Idrees et al., 2017). Garzon et al. (2013) analyzed the results obtained by questionnaires from several samples of construction workers from southern Spain. Their statistical study revealed that the worker safety attitude is influenced by the emotional state and work satisfaction level. Moreover, another research effort (Tixier et al., 2014) suggested cognitive interactions between emotions and risk perception. In other words, it was stated that there are measureable differences in construction safety risk perception among people with different emotional states. Han et al. (2014) indicated that the perception and attitude of construction workers vis-à-vis hazards on jobsites is mainly affected by work pressure and intensity, and whether or not a reward system is implemented for motivation purposes. In fact, many studies have stated that having the ability to identify hazard doesn't always mean workers possess the motivation to work safely (Mitropoulos et al., 2005; Perlman et al., 2014). They indicated that the motivation of workers to accomplish high levels of productivity drives them to work 'near the edge' when exposed to hazards. Alternatively, other researchers have described retrospective hazard recognition methods (i.e. lessons learned) that aim at inferring knowledge obtained from past safety incidents to motivate the on-site workforce in new situations and projects (Goh and Chua, 2010; Behm and Schneller, 2012; Jeelani et al., 2017). Other research efforts (Fang et al., 2015) conducted a 3-month questionnaire survey on several construction sites in Hong Kong, aiming to detect the impact of the supervisor on construction workers safety behavior. Results showed that a reactive and supportive action has a direct influence on worker safety perception and behavior but not on the overall safety climate, while a training and preventive action can tackle different aspects of safety climate (e.g. workplace hazard assessment) thereby enhancing safety conditions.

Nonetheless, none of the aforementioned research works opted for interactive surveys that have been widely used in other industries to obtain unbiased results or to avoid the receipt of deceptive information which may occur in face to face surveys. For instance, Sellmer et al. (2003) used touch-screen computers to conduct an interactive survey with the attendees at the 2001 Philadelphia Flower Show about their knowledge and use of plant health care and integrated pest management. This tool helped them in efficiently and precisely collecting data. Ker et al. (2008) conducted an interactive computer-based survey, using a digital image editing software package, to quantify the ideal and maximum acceptable deviations for smile characteristics. The raters were able to manipulate intraoral photographs presented in this survey, which allowed them to accurately select the ideal case for each featured smile characteristic. Other research efforts relied on card game surveys. Follin and Fischbeck (2001) employed a card game to evaluate several alternatives of a freeway design. Players were provided with cards, each showing seven features of a certain alternative design, and then were asked to rank the cards according to the features. Similarly, Li et al. (2014) employed an interactive card game survey was conducted to determine the information needed by fire responders to establish situational awareness during fire emergency response operations. More specifically, 29 first responders from the United States were provided with a set of cards containing each an information item. When put in front of an imaginary fire emergency scenario that was textually explained rather than graphically displayed, the players were allowed to ask for any information item they needed and for its update in order to establish a situational awareness of the emergency case. At the end of the game, the value of an information item was determined by evaluating three results: (1) the order it was requested, (2) the number of times that its update was requested, and (3) its overall importance ranked by the fire responders at the end of the survey. Other recent efforts (Bahn, 2013b; Bahn, 2014) have resorted to an interactive picture-based survey as a valid and useful assessment or data collection tool aiming at investigating the ability of new entrants to underground mining in effectively identifying hazards within their work areas.

3. Research gaps and contributions

As aforementioned, a recent research effort by Awwad et al. (2015) was the first study that shed light on construction safety practices and challenges in Lebanon by conducting survey questionnaires and semi-structured interviews with a limited number of construction stakeholders. The study helped in soliciting information about the existing safety environment, constraints hindering the development of safe work practices, and the role of different parties in bringing improvements to the Lebanese construction industry. However, it did not include the perspective of the construction workforce on safety, in particular on-site indoor hazards. In fact, a good safety education system ensures that the on-site workforce is aware of on-site hazards and is well-trained to deal with them. Therefore, one of this study's contributions lies in soliciting feedback from the on-site workforce in Lebanon, in particular engineers, foremen and most importantly workers as they are considered the frontline of the industry. Additionally, since most of the construction workers in Lebanon are foreigners and do not belong to any labor unions, they were not asked about the safety climate, self-reported work practices, and their wellbeing on jobsites like in other studies (Glendon and Litherland, 2001; Mohamed, 2002; Fang et al., 2006; Choudhry et al., 2009). The same applies to engineers and foremen. Instead, they were interviewed to mainly evaluate common hazardous activities and hardhat use with the aim of formulating their perception on construction hazards and safety-related matters.

On the other hand, several factors sought to impact the construction personnel perception towards hazards and safety-related matters, in particular on-site implementation of SHMS, site conditions and characteristics, position and years of experience, past incidents, and self-motivation, were actually: (1) not all addressed before in one research effort, as is the case of the present study, (2) not all taken into consideration when analyzing a survey dealing with the on-site workforce rather than other construction individuals, and (3) not all studied with the same focus as this paper especially when it comes to site characteristics and some influential factors such as past incidents, self-motivation, etc. Furthermore, assessing the impact of all these factors on hazard perception of construction personnel was never carried out previously in Lebanon. Hence, another contribution lies in adopting, in a single study, all these factors and in varying degrees to assess the perception of the Lebanese on-site workforce, in particular, towards hazards and hardhat use.

Moreover, as aforementioned in other studies, traditional survey questionnaires and interactive surveys such as card games or picture-based surveys (Sellmer et al., 2003; Ker et al., 2008; Li et al., 2014; Bahn, 2013b; Bahn, 2014) were used for data collection purposes. However, another interesting contribution of this research lies in extending previous work on interactive surveys, in particular picture-based ones conducted in the mining sector (Bahn, 2013b; Bahn, 2014), to the construction sector by designing a video-based interactive survey instead for data collection purposes. It was preferred over traditional survey questionnaires, card games, or picture-based surveys because it is capable of graphically mimicking the hazardous activity and quickly guiding the interviewed individual to assess the situation as the video is playing. It was as well deemed crucial for diminishing the Hawthorne Effect, which is commonly witnessed in studies using traditional surveys and questionnaires, whereby respondents may alter their perception and modify their answers when they know they are being observed. The proposed approach thereby allows construction personnel being interviewed to become more conscious of the displayed videos of hazardous cases and less conscious of the observation process.

4. Research methodology

4.1. Survey design

Further to a comprehensive review concerning the status of construction safety, particularly in developing countries, studies revealed a sizeable number of interacting elements affecting the level of health and safety on construction sites. As mentioned in the previous section, the perception of on-site construction personnel toward safety hazards

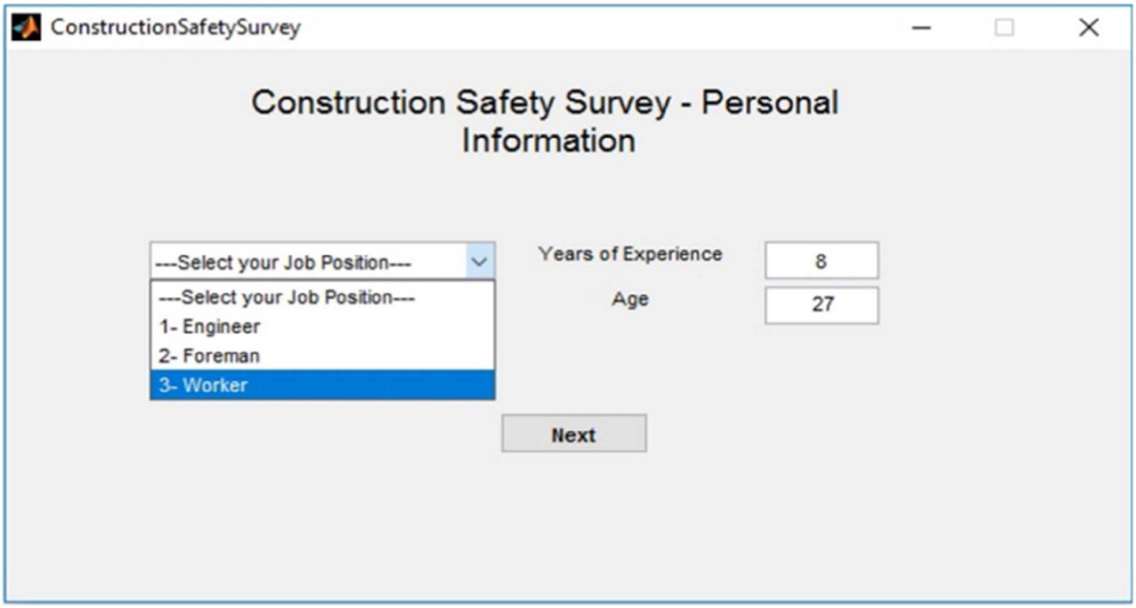

Fig. 1. Personal information window.

and their means of mitigation attracted many researchers for its significant effect in maintaining a safe construction environment. Results proclaimed numerous components impacting the hazard perception of the on-site construction workforce. In this study, a computer-based interactive graphical survey was conducted to assess the perception of engineers, foremen, and workers towards hazards and hardhat use, in particular, on different construction sites located in Lebanon. A graphical user interface (GUI) was implemented using MATLAB to collect data, and was divided into three main areas: (1) Personal background information, (2) hazard perception, and (3) hardhat wearing evaluation. Personal information includes the position or job title, age and years of experience of the interviewed individual (Fig. 1).

In the second part of the user interface application, the hazard perception section, interviewees were asked to grade some hazardous activities or scenarios. Since it is very difficult to interrupt the construction personnel, in particular foremen and workers, for a long period of time to ask them about all types of hazardous cases, the choice landed on only non-worker related indoor hazards. After conducting semi-structured interviews with workers from few sites, seven hazardous situations were identified as most critical in Lebanon due their severity and frequency of occurrence, namely: (1) Welding, (2) operating concrete mixer, (3) steel grinding, (4) stack of steel leftovers, (5) fire, (6) stack of gravel, and (7) unprotected openings. Various risks can be associated with each of the selected activities, and a relatively high level of awareness is required to detect all potential hazards (Table 1).

Table 1
Potential hazards associated with selected situation.

Situation	Potential Hazards
Welding	Fire and/or explosion
	Burns to the skin and eyes
Operating Concrete Mixer	Overturning and spoiling of concrete
	Electric shock
Steel Grinding	Inadequately mounted discs
	Particles in the eye
Stack of Steel Leftovers	Slips, trips and falls
	Wounds to the skin
Fire	Burns to the skin
	Explosion and/or damage to property
Stack of Gravel	Slips, trips and falls
	Injury due to unintentionally shot particles
Unprotected Opening	Slips, trips and falls
	Injury due to falling objects

As such, this section contains real pictures from construction sites to which seven different virtual videos of hazardous tasks and areas were superimposed and animated to reflect a more realistic view. Fig. 2 is an example of the grinding case.

The animated 3D videos augmented onto the real scene were created using 'After Effects' (Simons, 2013). Each of the seven selected hazardous cases was extensively designed and required its own set of effects, including but are not limited to the Particle System, Long Exposure, Color Stabilizer, Transition, Turbulent Noise, Puppet, Paint, and the Roto Brush effects, to render it more realistic (Figs. 2 and 3).

In this case, interviewees were asked to rate the severity of the encountered scene on a scale of 1–10, with 10 indicating most severe and 1 indicating least severe based on personal opinion and past experiences (Figs. 2 and 3). It is worth noting that construction personnel were interviewed about their perception on the severity of a specific hazardous activity with respect to nearby individuals rather than those executing the activity.

In the final section, hardhat evaluation, engineers, foremen and workers were invited to (1) evaluate, based on their perception, the hardhat wearing importance on a scale of 1–10, with 10 indicating most important and 1 indicating least important, (2) declare the reason that makes them wear the hardhat (i.e. personal incentive or imposed by the safety officer), and (3) state if they have experienced a previous incident whereby the hardhat saved them from getting injured (Fig. 4). As other PPE is almost non-existent, the focus was mainly on hardhat use.

The aforementioned software has a simple and user-friendly interface which people from different backgrounds, ages and educational levels can adopt. In addition, it is scalable and can be tailored for other surveys in the construction industry as well as other engineering fields such as fire emergency response.

4.2. Data collection

The interactive computer-based safety survey was carried out from July 2016 to January 2017 on seven construction sites, operated by seven distinct contracting companies, having different conditions and characteristics, and located in separate governorates of Lebanon. The construction sites were not straightforwardly accessible and as such, official site access permissions were granted following formal meetings with personnel from the head office in each of the seven contracting

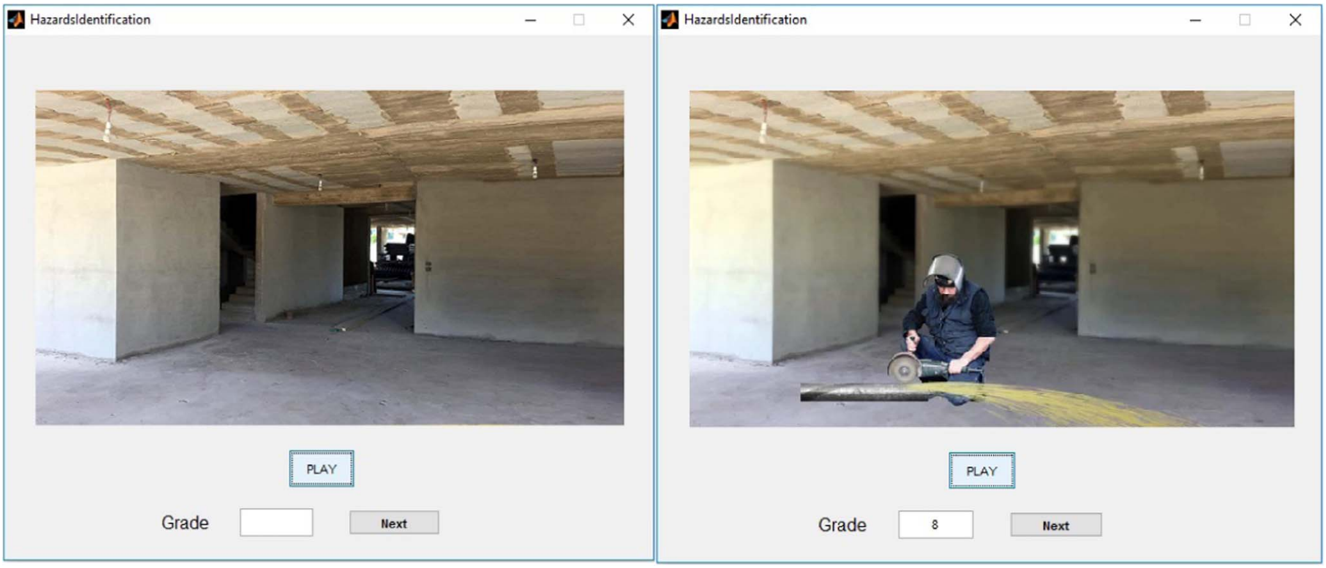

Fig. 2. Hazard identification window – Grinding.

companies. Table 2 outlines the features of the construction sites where interviews were conducted. This includes size, location, area of operation of the contractor in charge, the adoption of a SHMS and the number of interviewees.

Only three out of seven contracting firms had a SHMS in place. In Lebanon, according to interviewed contractors, a SHMS is subjectively based on a random combination of international standards or the contractor's proficiency and its main characteristics are mainly limited to: on-site safety signage, safety meetings, training sessions, regular site inspection by safety officers, PPE provision and enforcement, and worksite analysis. It is worth noting that not all characteristics are perceived equally by the contractors having a SHMS in place and are rather implemented in varying degrees due to the absence of unified safety and health regulations.

The size of the construction sites was classified into three categories based on the number of working staff: (1) "Large" for sites having more than 500 workers, (2) "Medium" for those having less than 500 and more than 50 workers, and (3) "Small" for those having less than 50 workers.

As shown in Table 2, a total of 285 construction personnel were interviewed, in particular engineers, foremen, and workers, with experience levels ranging from novice to expert. The distribution of interviewees according to their positions and practical years of experience is presented in Table 3 and Fig. 5.

4.3. Data entry and analysis

Data from the completed survey is entered and directly saved in a database (Table 4). Table 4 shows an example of five interviews' results saved by the software. The first column represents the interviewee's number, the second, third and fourth columns feature the position/job title, age and years of experience respectively. The grades given to the seven hazardous scenarios are saved in the columns A through G. The last three columns display the interviewees' answers to the questions related to hardhat presented in the last section of the GUI user application.

The obtained results are then assessed and statistically analyzed. To study the impact of SHMS, construction site characteristics, the position and years of experience on the hazard perception of construction personnel, the one-way analysis of variance (ANOVA) is utilized (Vijayvargiya, 2009; Foster, 1995). It is worth mentioning again that the impact of the aforementioned factors on hazard perception has been studied in prior research efforts, however not in Lebanon. Furthermore, since it was previously noted that there is a weak commitment of construction stakeholders to safety practices and an absence of enforcement of safety regulations in the Lebanese construction industry (Awwad et al., 2015), the hypotheses are formulated as follows:

- Null hypothesis H_0: The studied factor has no impact on the hazard perception of the interviewed construction personnel.
- Alternate hypothesis H_1: The studied factor has a significant impact on the hazard perception of the interviewed construction personnel.

Additionally, a test is conducted to study the impact of some influential factors (i.e. past incident, self-motivation) on the perception of on-site construction personnel towards hardhat usage when encountered with hazards.

The resulting p-value is then compared to a significance level alpha equal to 0.05, such that:

- If p-value is greater than alpha, there is no significant evidence to reject the null hypothesis.
- If p-value is less than alpha, the null hypothesis shall be rejected. Thus, the factor under consideration has a significant impact on the construction workforce perception of safety.

In order to analyze the results, R Studio was used. It is an integrated development environment (IDE) for the R programming language that is used for statistical computing and graphics (Kuhnert and Venables 2005).

5. Results and statistical analysis

Initial results highlighted discrepancies in the perception of risks associated to various situations. Collected scores' averages and standard deviations ranged from 2.05 to 10, and 0 to 1.83 respectively (Table 5).

According to the interviewed workforce, "Unprotected openings", "Fire", "Welding" and "Grinding" activities were considered the most hazardous. Since the "Unprotected openings" hazardous case was perceived equally (Standard deviation = 0) by the construction workforce, it was dismissed from later analyses. As for the evaluation of the hardhat importance, the average and standard deviation were 5.61 and 2.68 respectively.

In the following sections, the collected data is further analyzed statistically in relation to some factors (i.e. adoption of SHMS, site characteristics, job position, years of experience, etc.) to better infer

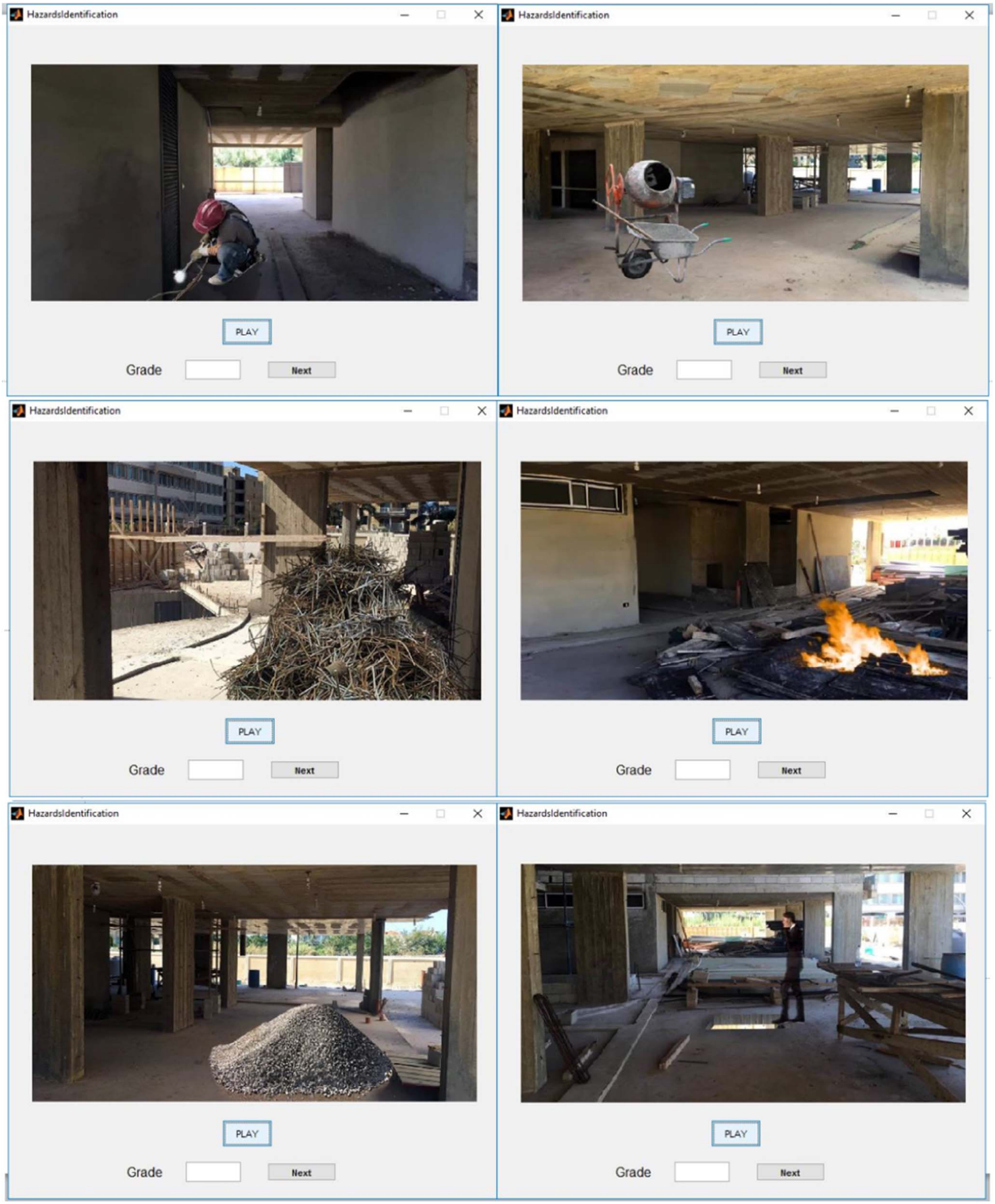

Fig. 3. Hazard identification window – Other hazardous scenarios (Welding, operating concrete mixer, stack of steel leftovers, fire, stack of gravel, and unprotected openings).

about the hazard perception of on-site construction personnel.

5.1. Impact of on-site implementation of SHMS on hazard perception

In order to assess the impact of SHMS adoption by contracting companies on the construction personnel hazard perception, construction sites with different levels of safety implementation were chosen. As aforementioned, the first three sites are operated by three different contracting companies that have a SHMS in place. However, the SHMS characteristics are applied in varying degrees as Lebanese contractors typically rely on a random combination of international standards such as US standards (OSHA), international British standards

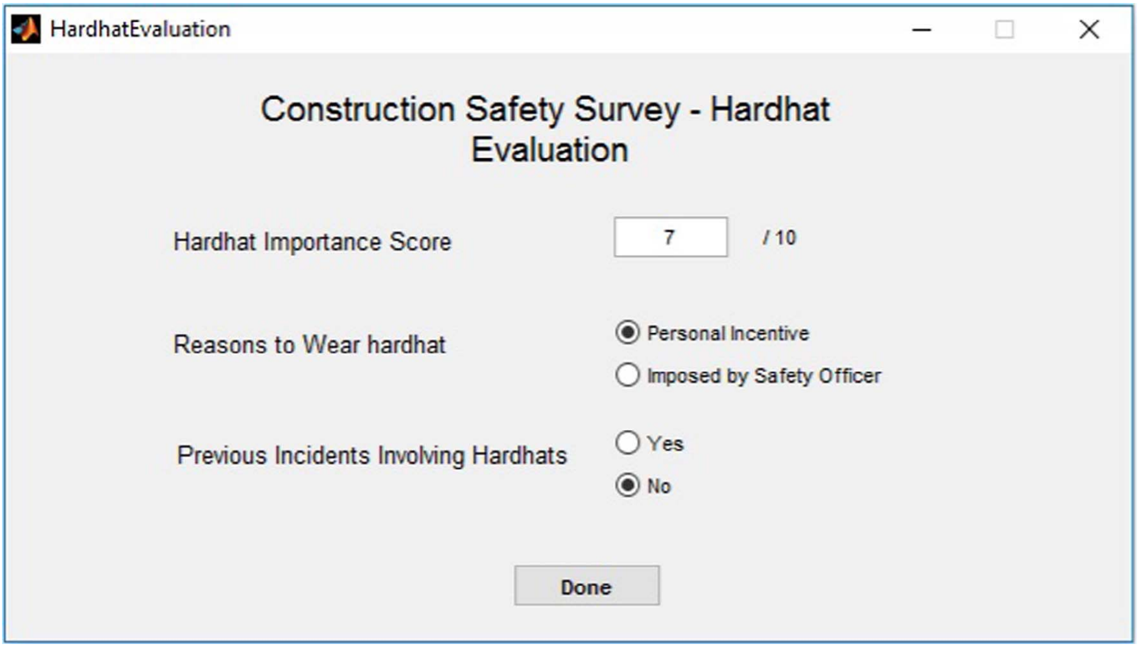

Fig. 4. Hardhat evaluation window.

Table 2
Construction sites features.

Site	Size	Location	Scope of Work	Contractor's Area of Operation	SHMS Adoption	Number of Interviews
1	Large	Mount Lebanon	Concrete	International	Yes	85
2	Large	Beirut	Concrete	International	Yes	60
3	Medium	Beirut	Concrete	International	Yes	50
4	Medium	North Lebanon	Concrete	Local	No	30
5	Small	Beirut	Finishing	Local	No	20
6	Small	Beirut	Concrete	Local	No	20
7	Small	North Lebanon	Steel	Local	No	20

Table 3
Interviewees distribution according to positions.

Position	Number of Interviewees
Engineers	36
Foremen	58
Workers	191
Total	285

(BS OHSAS 18001), and ISO (14001) beside their experience on prior projects due to the absence of a unified national safety and health management system. More specifically, the first site presented the highest commitment to safety and health regulations and mainly involved regular site inspections by several safety officers, weekly safety toolboxes, safety training sessions, in addition to safety regulations and signs posted on the jobsite to raise awareness towards potential site hazards. The second and third sites showed moderate safety management performance relying on a limited number of safety officers inspecting intermittently, as well as occasional safety meetings and training sessions. As for the last four sites, there were no onsite safety representatives, and the implementation of safety regulations was limited. The ANOVA test was utilized to detect and quantify the presence of reasonable differences between the first set of sites having SHMS in place (Sites 1–3) and the second set with no SHMS in place (Sites 4–7). Results revealed the absence of a significant difference between the two sets for all hazardous activities (p-value $> .05$) as opposed to the hardhat part (p-value $< .05$) (Fig. 6). This discrepancy in the ANOVA test results between the perception of hazardous activities and that of hardhat wearing infers that only few characteristics of SHMS are being implemented. In other words, the adoption of SHMS revolves mainly about imposing the use of hardhats by on-site safety officers rather than educating them, through safety meetings and trainings, on enhancing their awareness and perception of potential risks and hazardous activities.

5.2. Impact of site conditions and characteristics on hazard perception

The analysis in the previous section grouped sites according to adoption of SHMS. However, each site presents different overall characteristics and environment even when a SHMS is in place. Therefore, analyzing separately the site characteristics and conditions was warranted. For each site, the average scores obtained for the hazardous scenarios as well as for the hardhat importance are summarized in Table 6.

The ANOVA test was then applied on each of the hazardous activities' recognition grades and on the hardhat evaluation scores, thus obtaining eight p-values, and boxplots were used to visualize the data (Fig. 7).

Results indicated the absence of a significant difference (p-value $> .05$), for all hazards identification cases among the seven construction sites, except for the steel grinding activity (p-value $<$ .05). To further collate the performance of the various sites, a multiple-comparison test, in particular the Holm-Bonferroni Test (Siegel, 1956; Holm, 1979) was then applied. Results pointed out that the only site that witnessed a relevant difference is Site 7 by displaying the highest grades for welding and grinding and scoring among the lowest for all other activities. The low scores can be attributed to the absence of a SHMS. On the other hand, as aforementioned in Table 2, Site 7 involves steel erection works which are the not the norm in Lebanon as the majority of construction projects are concrete-based. Accordingly, workers were trained on steel construction practices as well as work-related risks, thereby providing higher rating for steel grinding and welding. As for the hardhat importance scores, a significant difference was noted (p-value $< .05$) with sites 1 and 2 scoring the highest

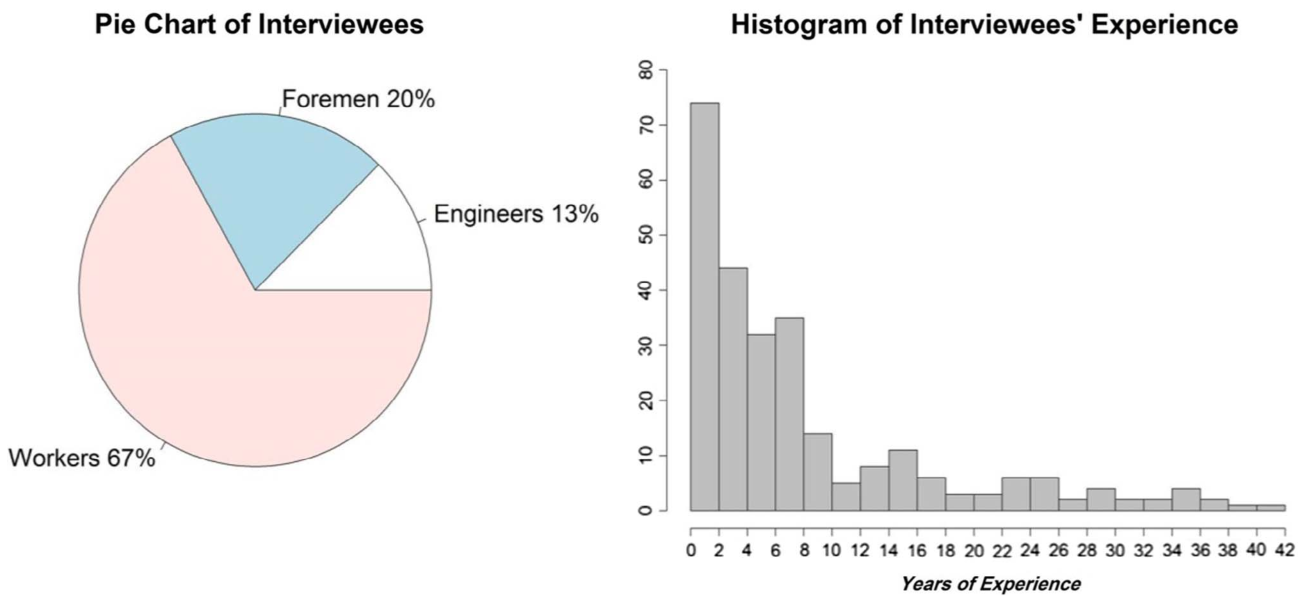

Fig. 5. Interviewees distribution according to position and years of experience.

Table 4
Sample results saved in the database.

#	Pos.	Age	Exp.	A	B	C	D	E	F	G	H	Wear Hardhat	Past Incidents
1	E	25	2	7	6	8	4	9	4	10	8	Yes	No
2	W	20	5	5	9	7	3	10	1	10	3	No	No
3	W	38	5	3	5	6	5	10	2	10	5	No	No
4	W	20	1	5	3	8	7	10	1	10	1	No	No
5	W	18	1	7	5	10	8	10	1	10	4	No	No

Table 5
Hazards score's averages and standard deviations.

Situation	Average	Standard deviation
Welding	5.68	1.78
Operating Concrete Mixer	2.96	1.68
Steel Grinding	6.61	1.74
Stack of Steel Leftovers	3.04	1.83
Fire	9.14	1.14
Stack of Gravel	2.05	1.32
Unprotected Openings	10.00	0.00

because safety officers were present and sites 5 and 7 scoring the lowest. This infers that despite educating workers of potential work-related risks, as is the case of Site 7, the presence of safety officers on jobsites is important to continuously enforce safety regulations and provide a healthy and safe environment.

5.3. Impact of on-site construction personnel position on hazard perception

Construction staff positions may also impact the hazard perception and awareness. The three major positions encountered on construction sites were: (1) Engineers, (2) Foremen, and (3) Workers. The average scores obtained, for the hazardous scenarios, as well as for the hardhat importance are summarized in Table 7.

Based on the results obtained from the ANOVA statistical analysis (Fig. 8), the null hypothesis was rejected as all calculated p-values were noticeably smaller than 0.05. As such, it can be concluded that the personnel position has a significant impact on his perception of hazards and evaluation of hardhat-wearing importance. In fact, engineers displayed moderately high levels of hazard perception, followed by foremen, while workers' perception levels were relatively poor. The high awareness levels of engineers can be attributed to the fact that they are top-tier students who have completed a minimum of four years of college education and are typically very well trained. On the other hand, foremen are skilled workers holding a vocational degree in a related field and have acquired the needed knowledge rendering them aware of typical hazards. Workers are unskilled foreign individuals mainly of Syrian origins working at low wages and as such, have no incentive in enhancing their awareness of common hazards. Nonetheless, unskilled workers showed a better perception of fire-related risks as opposed to other hazards, which are typically encountered in other environments. Therefore, unskilled workers need to be actively educated on safety related issues.

5.4. Impact of on-site construction personnel experience on hazard perception

A study conducted by the Institute for Work and Health (IWH) suggested that new employees are a lot more prone to injury than those who have been working for over a year and suffer about one third of the total construction related injuries (Trotto, 2016). This higher risk of injury might be attributed to a poor perception of safety due to the lack of experience of construction personnel. Thus, the experience factor was considered in this study. The interviewees' years of experience were divided into six classes: (1) from 0 to 1 year, (2) from 2 to 3 years, (3) from 4 to 6 years, (4) from 6 to 9 years, (5) from 10 to 19 years, and (6) plus 20 years of experience (Fig. 9).

The average scores obtained, for the hazardous scenarios, as well as for the hardhat importance are summarized in Table 8.

Results from the ANOVA test (Fig. 10) revealed a significant difference between the obtained grades according to the years of experience, except for the "Operating Concrete Mixer" and "Stack of Gravel" scenarios. As shown in Fig. 10, with higher years of experience, obtained scores may increase (Steel Grinding and Hardhat Importance), decrease (Fire), or fluctuate (Welding and Steel Leftovers). This discrepancy in hazard perception according to years of experience is alarming and calls for a proper and continuous safety education and training of the construction workforce.

5.5. Impact of other influential factors on hardhat evaluation

A last test was carried out to study the impact of some influential

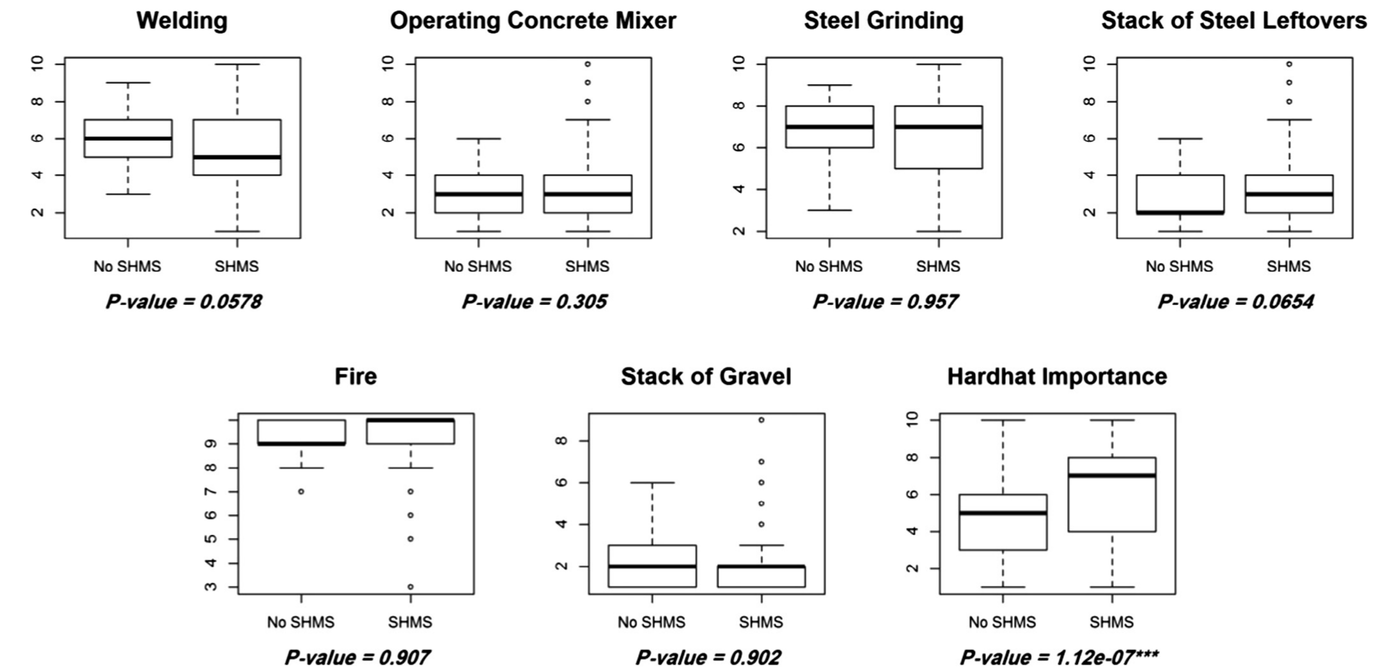

Fig. 6. Impact of SHMS on hazard perception.

Table 6
Average scores obtained for different construction sites.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Welding	5.69	5.52	5.34	6.13	5.70	5.55	6.45
Operating Concrete Mixer	2.99	3.12	3.00	3.13	2.40	2.80	2.75
Grinding	6.21	6.72	7.16	6.63	6.05	6.35	7.45
Stack of Steel Leftovers	2.98	3.42	3.22	2.67	2.70	3.10	2.55
Fire	8.91	9.37	9.26	9.23	9.10	9.15	9.10
Stack of Gravel	1.94	2.17	2.20	2.03	2.00	2.10	1.85
Hardhat Importance	6.65	5.83	5.78	5.23	3.80	4.20	3.95

Table 7
Average scores obtained for different positions.

	Engineers	Foremen	Workers
Welding	7.31	5.57	5.34
Operating Concrete Mixer	4.75	3.40	2.54
Grinding	8.19	6.98	6.13
Stack of Steel Leftovers	4.88	3.83	2.53
Fire	9.31	7.77	9.52
Stack of Gravel	3.88	1.96	1.78
Hardhat Importance	7.67	8.13	6.13

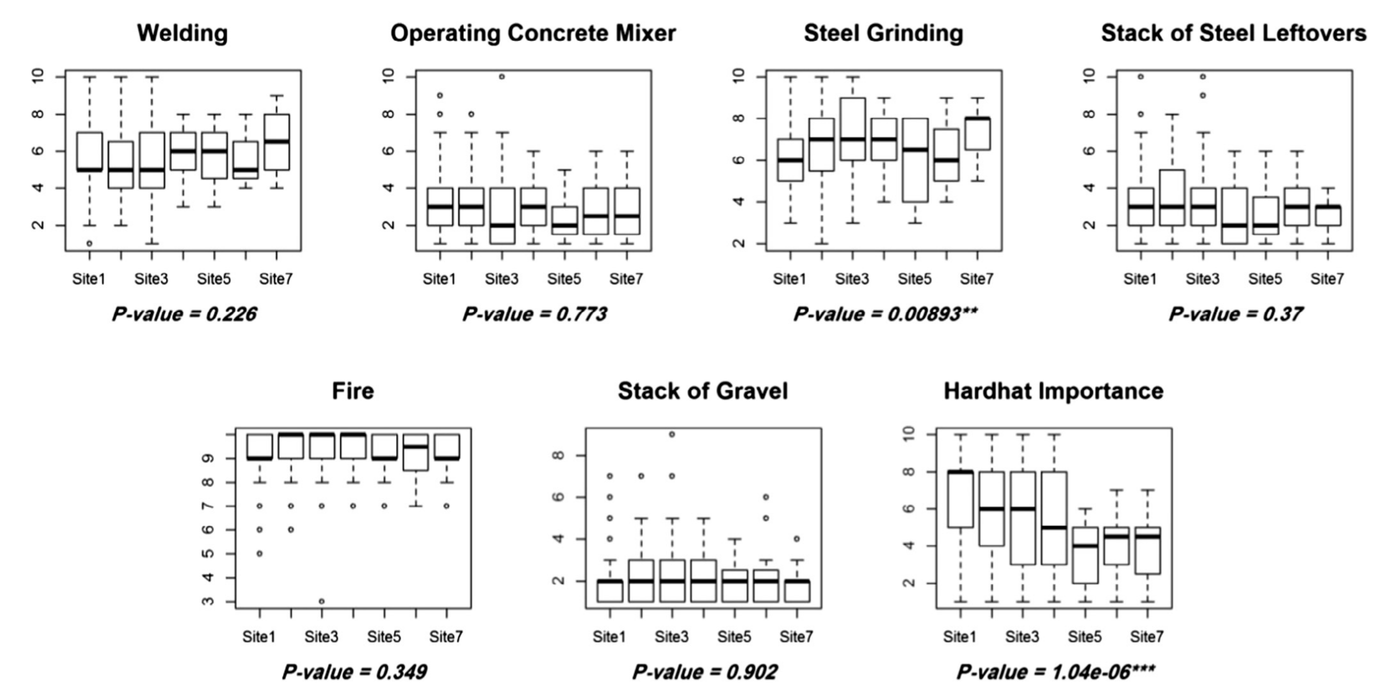

Fig. 7. Impact of site characteristics on hazard perception.

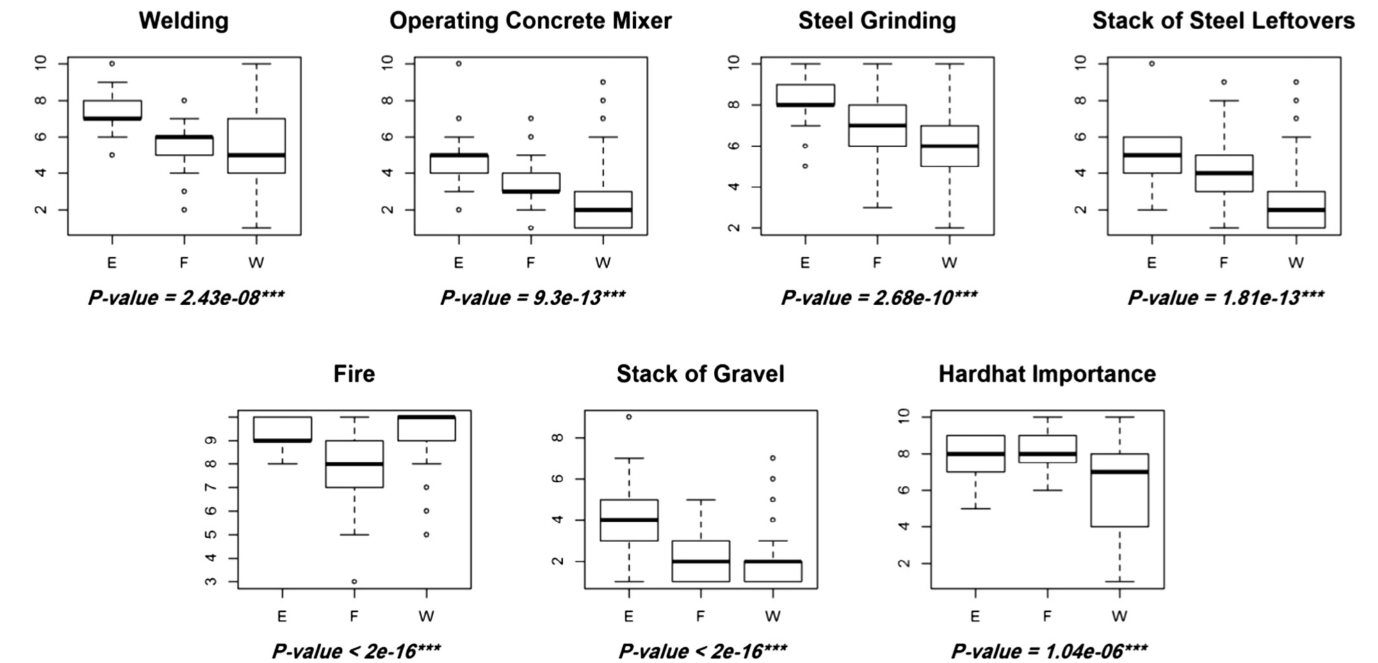

Fig. 8. Effect of positions on hazard perception.

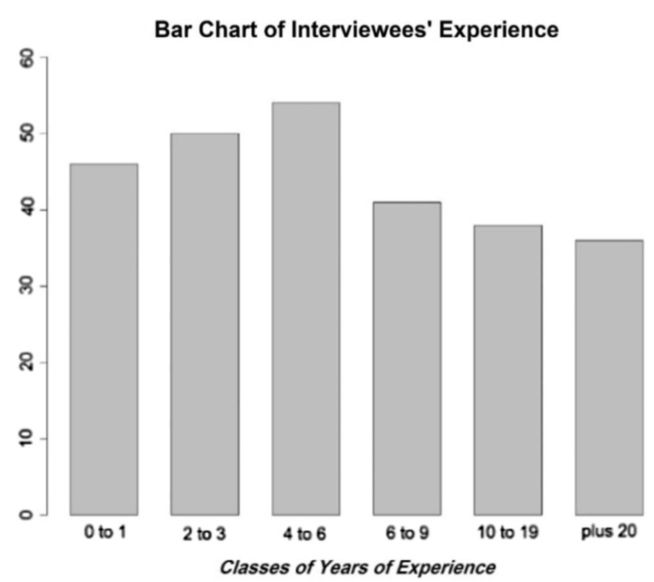

Fig. 9. Distribution of interviewees according to classes of experience.

Table 8
Average scores obtained for different classes of years of experience.

	0–1	2–3	4–6	6–9	10–19	> 20
Welding	4.65	5.64	5.61	6.41	5.89	5.69
Operating Concrete Mixer	2.52	2.76	2.81	3.15	3.45	3.42
Grinding	5.89	5.92	6.43	7.02	7.34	7.08
Stack of Steel Leftovers	2.80	2.50	2.81	3.17	4.08	3.44
Fire	9.46	9.32	9.59	9.61	8.66	7.83
Stack of Gravel	2.13	2.10	1.91	2.10	2.42	1.78
Hardhat Importance	5.56	5.30	6.57	8.00	7.91	8.64

factors (i.e. past incident, self-motivation, and enforced regulations) on the perception of on-site construction personnel towards the importance of hardhats when encountered with hazards. As such, interviewees were asked about the reason behind wearing a hardhat and whether it was out of personal incentive or it was imposed by safety officers (Fig. 4). The survey includes as well a question on past incidents, whereby the answer "Yes" indicates that the construction personnel or any of the co-workers, have previously been protected from any sort of minor or major head injury by wearing a hardhat. The summary of results is presented in Table 9.

According to Table 9, the following findings can be formulated:

- 27% of all interviewees had previous incidents involving hardhats and 73% did not.
- 47% of the total interviewees would wear a hardhat out of personal incentive while 53% would not.
- 79% of interviewees who had a past incident would wear a hardhat out of personal incentive and 65% who have not experienced a past incident would only wear a hardhat whenever it was imposed by safety officers.

The last finding clearly implies that the use of hardhat is limited to having survived an incident despite it being a common safety practice. This is highlighted through the average hardhat score that was computed as 4.88 in the case of individuals who have not previously experienced any incident compared to 7.55 for individuals who have experienced a past incident. In order to further assess the impact of past incidents on the hardhat appreciation score, the ANOVA test was utilized. Results (Fig. 11) revealed as well a significant difference in the score value between both classes of individuals. It was noted as well that some interviewees had the personal incentive of wearing a hardhat even in the absence of past incidents which is actually due to the adoption of SHMS, hence a high hardhat evaluation score. Overall, the test results clearly reflect how the main incentive behind wearing a hardhat is actually having faced past incidents and avoiding future ones or having it imposed by safety officers in lieu of self-motivation.

6. Discussion and recommendations

Survey findings revealed a lack of on-site personnel awareness and perception vis-à-vis hazardous activities and hardhat use in the Lebanese construction industry. First, the impact of having a SHMS in place on the on-site personnel awareness towards potential hazards was found to be not significant. However, this was not the case for the

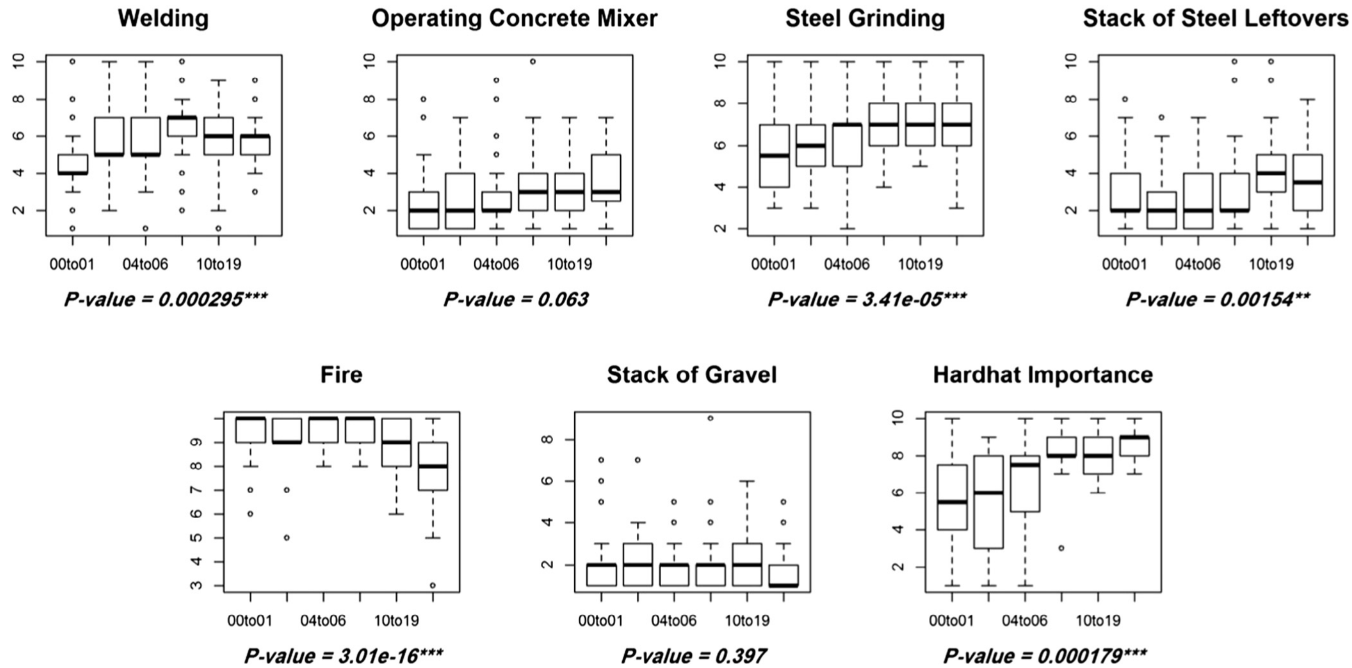

Fig. 10. Impact of experience on hazard perception.

Table 9
Hardhat evaluation test results.

		Reason to wear a hardhat		
		Personal incentive	Imposed by safety officers	**Total**
Past incident	Yes	62	16	**78**
	No	71	136	**207**
	Total	**133**	**152**	**285**

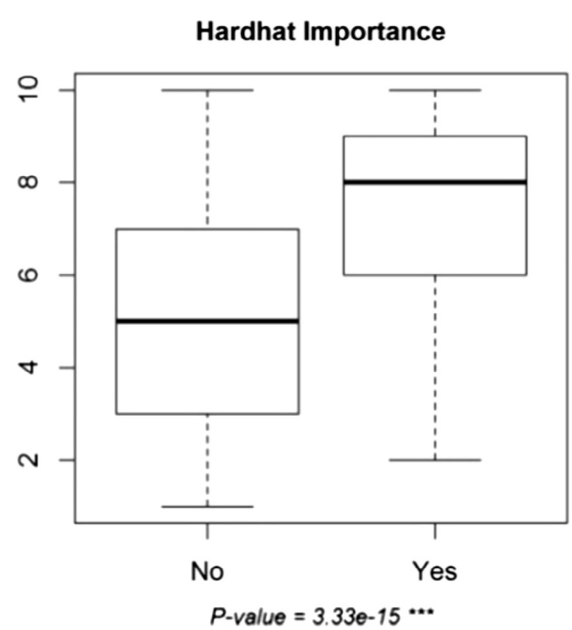

Fig. 11. Impact of past incidents on hardhat evaluation.

evaluation of hardhat use. This implies that Lebanese contracting companies are failing at properly implementing various characteristics of a SHMS and are mostly focusing on having safety officers impose hardhat use without adequately investing in educating workers through mainly safety meetings and training sessions. Additionally, SHMS characteristics were applied in varying degrees among the first three sites. On the other hand, properly training construction personnel on some work-related risks while refraining from hiring safety officers to ensure compliance with safety regulations and from devising safe work practices is also doomed to fail. As such, it is of paramount importance to have a unified SHMS in place and implement all its characteristics without compromising one over the other.

On another hand, the impact of construction personnel position on hazard perception was found to be significant and results revealed a better perception of hazards by engineers in particular. As for the effect of construction personnel years of experience on their hazard perception, results revealed, in most part, a significant difference, however, inconsistent, signaling a poor and discontinuous safety education. In other words, although years of experience should expand the individual's overall knowledge, a decisive judgment regarding its impact on the hazard perception could not be established due to a lack of continuous learning. While it can be associated with experience, proper learning cannot be achieved without a healthy and safe environment that goes beyond the presence of safety officers and imposed safety regulations, and rather involves effective safety trainings, toolboxes, situational awareness enhancement, etc., in other words the effective adoption of a SHMS. Accumulating years of experience on construction sites that fail to provide the aforementioned conditions would have little implications on the personnel hazard perception and risk assessment which, according to this study, is the case of the Lebanese construction industry.

In the last analysis, the impact of some other influential factors (i.e. past incidents, self-motivation, etc.) on the perception of on-site personnel towards hardhat usage when exposed to hazards was studied. Results showed that the majority of interviewees who had a past incident would wear a hardhat out of personal incentive while the majority of those who have not experienced a past incident would only wear a hardhat whenever it was imposed by safety officers (i.e. 48% of interviewees). This clearly reflects how the main incentive behind wearing a hardhat is actually having faced past incidents and avoiding future ones or having it imposed by safety officers in lieu of self-motivation. Although it was noted that some personnel (i.e. 26% of interviewees) had the personal incentive of wearing a hardhat even in the absence of past incidents due to the adoption of SHMS (i.e. high hardhat evaluation score), an absence of awareness towards potential hazards and an unsafe-conscious workforce can be noted in the Lebanese construction industry. Needless to say, other PPE was almost non-existent.

In light of the above, there is a great need to have unified national safety standards which all contracting companies should abide by instead of resorting to their own experience or their own interpretation of international standards. It is worth noting that the existing Lebanese safety regulations, stipulated through the governmental safety decree #11958, are not being strictly enforced and lack as well the specificity found in US OSHA 1926 requirements (Awwad et al., 2015). They mainly focus on general mitigation measures that need to be taken when encountered with on-site hazardous conditions rather than on proactive precaution measures. As such, it is recommended to devise new, specific and detailed safety legislations and strictly impose them across the nation. One of these guidelines should preferably aim at having the contractors conduct a thorough hazard assessment in line with OSHA 1910.132 (d) (OSHA, 2016). A hazard assessment is the process of identifying the hazards associated with a defined on-site task and suggesting relevant protection measures needed to lessen the risk from the hazards. In order to achieve that, the authors have designed a preliminary user-friendly interface application that can be adopted in the hazard assessment process (Fig. 12) as well as can educate workers on safety. Inspired from the “Activity Risk Assessment Handbook” (HSE, 2016), it comprises 85 different construction activities, the risks associated with each activity and the precautions that need to be taken to avoid accidents.

Additionally, in order to improve the chances that a unified SHMS will deliver the desired results, it is recommended as well that employers continuously solicit workers’ feedback on safety issues and follow-up on safety performance. Needless to say, devising effective safety and health guidelines can help contracting companies in efficiently designing their training programs targeted at educating on-site construction personnel on safety-related matters.

7. Conclusion and future work

On-site construction personnel perception and awareness towards hazards is of utmost importance in properly managing health and safety as well as reducing work-related accidents on construction sites. Hence, this study focused on quantifying this aspect through an interactive survey that was carried out on engineers, foremen and workers, on multiple construction sites located in various areas across Lebanon, a Middle Eastern developing country. More specifically, the interactive computer-based safety survey was carried out on seven different construction sites operated by seven separate contractors. Test subjects were asked to rate the severity of seven hazardous scenarios vastly encountered on construction sites on a scale of 1–10, with 10 indicating most severe and 1 indicating least severe based on personal opinion and past experiences. A thorough statistical analysis was then utilized to determine the factors affecting the hazard perception of construction personnel. Results indicated that an individual position and level of education have the most influential effect on the perception of safety. On the other hand, the adoption of SHMS by contracting firms on various construction sites and the increase in years of experience of personnel had little effect on their perception. Worryingly, a large proportion of the construction labor force was unable to perceive risks associated with situations occurring frequently on construction sites. In fact, it was observed that the adoption of SHMS is solely limited to imposing hardhat use by on-site safety officers while dropping other characteristics. Furthermore, the majority admitted that they would only wear a hardhat whenever it was imposed by a present safety officer and only past incidents where hardhats saved workers motivated them and had a great impact on their awareness.

The main contributions of the present study lie in: (1) assessing the on-site workforce hazard perception in the Lebanese construction sector through a set of factors, and (2) resorting to a video-based interactive survey rather than traditional questionnaires, card games, or picture-based surveys for better response rates and results. As a matter of fact, this latter approach was well entertained by the workforce who was very cooperative and quick in answering. It is worth noting again that construction personnel were not asked about the safety climate, self-reported work practices, and their wellbeing on jobsites. They were rather interviewed about (1) their perception on the severity of hazardous activities or areas with respect to nearby individuals rather

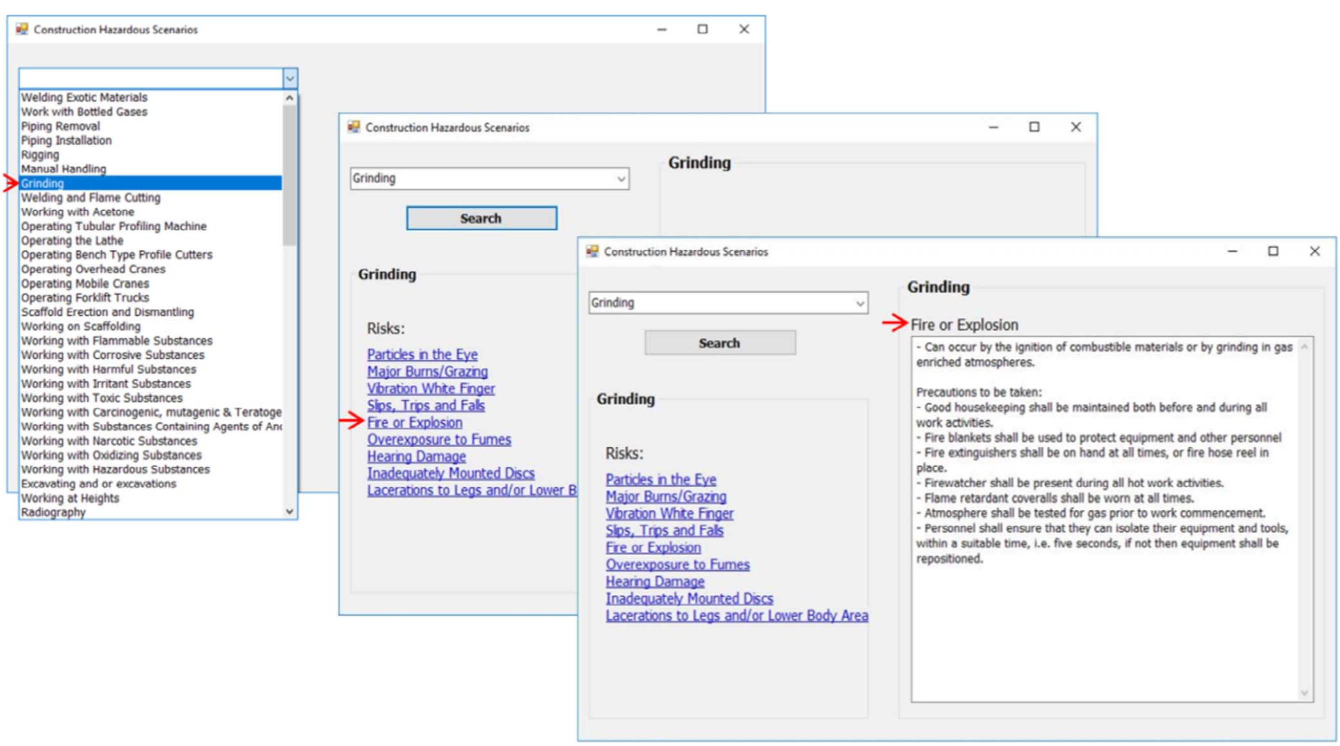

Fig. 12. Hazard assessment user interface application.

than those executing the activity, and (2) their perception on the importance of hardhat use when exposed to hazards.

Future efforts will be needed to conduct surveys on a larger number of construction sites presenting different environments, while asking about other hazardous conditions that are worker-related (e.g. scaffolding) and other PPE (if any) in order to formulate a better synopsis of the safety performance on Lebanese construction sites. Additionally, the interactive software application will be improved graphically to include other scenarios together with associated precautions. Further research will attempt at developing a comprehensive safety framework to help governmental authorities in better implementing their safety regulations and contractors. Additionally, a new system will be devised to effectively train the on-site labor force on safety-related matters within a virtual environment by means of a game engine rather than resorting to traditional, poor, and unengaging training practices. This will include an iterative process of testing until a satisfactory level of knowledge, skill, and attitude is achieved allowing thereby construction personnel to better implement situational awareness in the presence of changing on-site hazardous situations and rapidly make informed decisions.

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