AN AUTOMATED SAFETY PLANNING APPROACH FOR RESIDENTIAL CONSTRUCTION SITES IN MALAYSIA

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Abstract

Construction continues to be considered as one of the most dangerous industries in the world, in particular residential building construction. This paper aims at proposing an Automated Safety-Planning Plug-in (ASPP) for project scheduling software applications, to mitigate the occurrence of construction accidents. To achieve this aim, frequency and severity of the common construction safety hazards in residential buildings were investigated by distributing a questionnaire to safety managers and construction managers in Malaysia. A total of 106 completed responses were received. Then, risk level associated to each hazard was calculated based on the relevant risk matrix. The ASPP extracts current construction activities from any computer based schedule (Microsoft Project® in this paper) and identifies their risks level as well as safety regulations and hazards related to each activity as a report. A case study is used to investigate the reliability and usability of the ASPP. The ASPP was found to be efficient and helpful for rigorously complying with safety regulations and control potential hazards. The practical implication of this study is to improve construction safety by promoting the project managers' awareness of safety hazards and associated risks as well as essential safety indicators provided through a comprehensive report.

Keywords

Automated Safety-Planning Plug-in, Construction planning, Construction scheduling, Risk assessments, Safety hazards.

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INTRODUCTION

Construction is often the largest source of employment in any country (Hadikusumo and Rowlinson, 2002). It has been well documented that a large number of accidents have been recorded in this industry (Gregory and Simon, 2006, Wang et al., 2006, Hadikusumo and Rowlinson, 2002, Camino et al., 2008). In modern society, the construction industry has been defined as a dangerous industry (Liao and Perng, 2008, Niza et al., 2008). In the United States, the fatality rates in the construction sector were responsible for 11.1, 10.9 and 10.5 per 100,000 workers in 2005, 2006, 2007 respectively (Zhang and Hu, 2011, McLaughlin et al., 2004). In Korea, the construction industry accounted for less than 10 percent of gross domestic product in 2007, while its occupational fatalities accounted for 20 percent of total fatalities (Kim et al., 2010). In Taiwan, occupational fatalities accounted for 0.29 deaths per thousand construction employees in 2005, which was a much higher than fatality rate of all other industries (0.0657 deaths per thousand employees) (Cheng et al., 2010). In Hong Kong, the construction accident rate was approximately 68.1 per 1000 workers, which is high compared to other industries (Ling et al., 2008). In addition, as a consequence of the rapid growth of the construction industry in Malaysia, the rate of fatalities within this industry is alarming. The number of fatalities in this sector is accounted for about 32 percent out of the total fatalities accidents reported in 2009 which is higher than the manufacturing industry and agriculture industry which are recorded 28 percent and 19 percent fatalities respectively (Song et al., 2006).

The first essential step to mitigate construction accidents and manage safety is safety planning, which consists of identifying all probable hazards and safety measures. In order to manage and control construction hazards, consideration should be given to the prevention of hazardous events and efforts to limit the severity of occurred hazards (Gregory and Simon, 2006). In addition, to identify required safety measures, safety planning should be executed before conducting each construction activity. It is possible to enhance safety planning by determining safety hazards, classifying risks, controlling the risks and monitoring construction safety implementation (Chantawit et al., 2005).

Although, it is important to link the safety planning and project planning/scheduling task, safety planning was traditionally separated from the construction schedule. While by integrating safety planning and project planning, safety managers are able to recognize when, where and why safety measures on the safety plans must be used (Chantawit et al., 2005). Unfortunately, however, there is no comprehensive pattern for construction managers to follow to ensure safety planning on projects (Dejus, 2007). Management needs a reliable source of comprehensive information on safety hazards and safety measures. Such a system will enable managers to be aware of current hazards and risks in order to promote safe performance on their construction sites.

This study aims at proposing an Automated Safety-Planning Plug-in (ASPP) to integrate construction schedules with construction safety databases including construction safety hazards databases, risk assessment databases and construction safety measure databases. Such a system can be used to automate safety planning and enhance safety knowledge of construction practitioners so as to assist in reducing the rate of occurrence of accidents in the construction site.

Overview of Previous Approaches

In the past few decades, many researchers have focused on the potential use of information technology in the construction safety domain. Digital technologies, such as the online databases (H. Yu, 2009, Carter, 2006), Virtual reality (VR) (Hadikusumo and Rowlinson, 2002, Hadikusumo and Rowlinson, 2004), Geographic Information Systems (GIS) (Cheng et al., 2002, Bansal, 2011), Four Dimensional Computer-aided Design (4D CAD) (Zaki, 2006, Benjaoran and Bhokha, 2010), Building Information Modeling (BIM) (Hu and Zhang, 2011, Zhang and Hu, 2011), and sensing/warning technologies (McLaughlin et al., 2004, Song et al., 2006), can be widely applied in the construction phase to mitigate accidents on construction sites(Zhou et al., 2012). Table 1 summarizes some of the current research on digital technology implementation in the safety domain.

Table 1 Applied digital technology safety tools/ projects in construction

Year	Tools/ Projects	Features	Citation
2006	An automated model to monitor fall hazards	The model identified the risk of falling from heights and assigned associated safety regulations based on the current activities.	[28]
2006	A prototype to improve hazard identification and the subsequent assessment of risk	The prototype provided safety risk assessment and hazards associated to construction.	[16]
2009	A mobile phone application using the iPhone development platform	The model provided a wide range of safety-related information for users.	[29]
2009	A risk assessment model	The model identified and predicted the existing risk levels for major construction trades.	[30]
2009	A safety monitoring system using a mobile sensing device	The system reduced fatal accidents by monitoring places that are disposed to fall accidents.	[31]
2010	A 4D solution for safety related planning activities	The study demonstrates a method to integrate safety planning with BIM tools using commercially available software.	[32]
2011	A 4D-based model to manage conflicts and enhance Safety	The model analyzed the structure to find a hazardous area, having maximum slabs' displacements	[23]
2011	A proactive system for real-time safety management in construction sites	The study developed and tested a prototype for proactive safety management and real-time alerting against potential overhead hazards.	[33]
2011	A GIS based model for safety planning	The study integrated a 3D model with project's schedule and topography to find hazardous situation and correct planned sequence before actual implementation.	[20]

In spite of the importance of coordination safety planning with scheduling to discover the hazardous situations during the lifecycle of the project (2006), there is little research focused on a model to integrate scheduling software with safety hazard information. Navon and Kolton (2006) established a model to automate fall prevention procedures. The prototype detected the hazardous activities in the schedule and identified dangerous areas of the building. Lee et al. (2009) designed a safety monitoring system in order to reduce the rate of fatal accidents on construction sites. The system allowed real-time monitoring performance and prompt manager responses for safety management. The drawback of these two systems is they only focus on fall accidents.

Gangolells et al. (2002) demonstrated a method to calculate the risk of residential construction design safety-related performance. Many of the previous research have identified the existing hazards on the construction site and developed safety measures to minimize construction accidents, but there is no specific study of automatic computer-based models that determine the risk level of construction activities. All these studies just provide basic information which is not adequate for predicting what the accidents may be, when and where they will happen, and how they can be prevented. For such anticipations, an interaction between safety planning and scheduling can be helpful (Yi and Langford, 2006), but based on the current literature, there is a lack of a safety model that can be fully integrated with a construction schedule. Such a model would be able to determine the risk level of construction activities and report the current hazards on the construction site based on the applicable safety regulations. This paper contributes to the body of knowledge by developing an automated computer-based safety planning tool for residential buildings. This contribution will help project/safety managers, especially less experienced managers, to access a comprehensive overview of probable accidents and safety measures across construction processes.

Research Overview

The main steps, which were undertaken to achieve the aim of this study, are summarized in Figure 1.

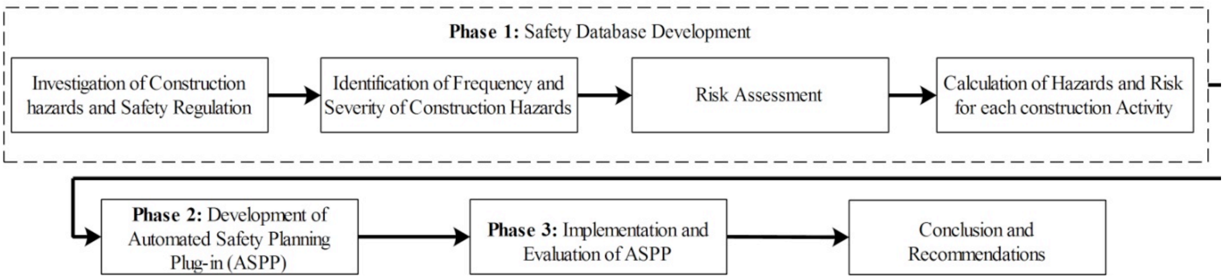

Figure 1 Research methodology

The methodology of this research consists of three phases: phase 1- development of safety database, phase 2- development of the ASPP, and phase 3- implementation and evaluation of the ASPP. The first phase includes four categories, namely the investigation of construction hazards and safety regulations via literature review and statistics, identification of construction hazards' frequency and severity via questionnaire survey, risk assessment of construction hazards using risk assessment formula, and calculation of hazards and risks for each construction activity via interview. The second phase comprises the design of ASPP using Microsoft visual basic for application and the third phase involves evaluation of ASPP using a case study. The details of development process are described in the following sections.

Safety Database Development (Phase 1)

Construction safety hazards and safety indicators

The most common safety hazards in the construction of residential buildings were investigated by reviewing previous research, including (Abdul Rahim et al., 2008, Zaki, 2006, Tam et al., 2004, Gervais, 2003, Lubega et al., 2000, Pipitsupaphol and Watanabe, 2000, Tam and Fung, 1998, Kartam and Bouz, 1998 , Hinze and Raboud, 1988, Hinze, 1981, Heinrich, 1980). In addition, the safety indicators were extracted from the Malaysian version of the USA's Occupational Safety and Health Administration (OSHA).

Frequency and severity of hazards

A questionnaire survey was developed to investigate the frequency and severity of common construction safety hazards in residential building in order to assess the risk level of each hazard. The questionnaire design was adopted from Fan and Yan (2010) and had four stages. In the first stage of the development of the survey, a pilot survey was conducted to test and optimize the length, format, and order of the questions to ensure that the final survey fulfilled the objectives of the study. The pilot study was initially accomplished with six safety managers who had more than 10 years of experience and broad knowledge in the construction safety domain. They were requested to review the relevance, consistency and the accuracy of the questionnaire. As a consequence of the pilot survey, a number of modifications were made.

In the second stage, some of the Web delivery factors concerning the survey, such as delivery modes for contacting potential participants, the design of the invitation for potential survey participants, and a schedule for sending reminders were decided. In the third stage, the questionnaire was developed using multiple-choice and Likert scale questions in two main sections for ease of use (Table 2). Section A covered the background and general information concerning the respondents, and section B asked the respondents to rank the frequency and severity of hazards across residential building construction. Finally, the questionnaire was distributed based on the cluster sampling method. The sample population consisted of construction managers, safety managers, and safety officers in Malaysia. The research included all sizes of organizations within the architecture, engineering, and construction (AEC) industry. An email survey is chosen in order to achieve the best coverage possible throughout Malaysia. Construction managers, safety managers, and safety officers from different companies from 13 Malaysian states were, randomly chosen by searching local Internet-based Yellow Pages. During February 2011, the questionnaire was sent to a total of 217 potential respondents. The respondents were requested to complete the questionnaire and rate the frequency and severity of each safety hazard across construction of residential buildings, based on their knowledge and experience.

Table 2 Likert scale used to determine the level of frequency and severity

Scale	Severity	Descriptions	Frequency
1	Insignificant	First aid injuries only and/or minimal impact	Never
2	Minor	Minor injuries and/or short-term impact	Unlikely
3	Moderate	Serious injuries and/or significant impact	Possible
4	Major	Fatalities and/or major short-term impact	Likely
5	Catastrophic	Large number of fatalities and/or major long-term impact	Always

A total of 106 (out of 217) completed responses were received, representing a response rate of 49 percent (n=106) which is acceptable according to Shih and Fan (2009). In addition, the reliability of the Likert scale was tested using Cronbach's alpha coefficient. According to Pallant (2001), a coefficient greater than 0.7 would be considered a reliable scale. The obtained alpha score from factor analysis is 0.869, meaning highly interrelated data and consistency of the scale with the sample size (n=106).

Only 12 percent of the respondents had less than five years of experience, while about 65 percent had over 10 years of experience. Almost 35 percent of respondents had less than 50 employees in their projects, 20 percent had between 51 and 150 employees, and about 45 percent engaged more than 150 employees. The annual revenue of around 32 percent of respondents' companies was less than USD 3.3 million, which is approximately10 million Ringgit Malaysia (RM 10 million). Similarly, 25 percent of companies earned between USD 3 million (RM 10 million) and USD 8.3 million (RM 25 million), and about 43 percent of the companies obtained more than USD 8.3 million (RM 25 million).

Risk assessment

Assessment Methodology: In the context of projects, risk is an event that, if occurs, can adversely affect the achievement of the project objectives (Carter, 2006). The causes of construction accidents are attributed to irresponsible underestimation or acceptance of risk which resulted to the hypothesis that misperceived risk or consciously accepted risk is a major cause of accidents (Benjaoran and Bhokha, 2010). Determining the rate of risk for construction hazards depends on the probability of an accident occurring and, its severity (Carter, 2006). Probability or frequency is defined as a likelihood of a hazard's potential being realized and initiating an incident or series of incidents that could result in harm or damage. The severity of the consequences is defined as the extent of harm or damage that could result from a hazard-related incident (Manuele, 2006).

Risk management comprises four interdependent elements: (1) hazard identification, (2) risk analysis, (3) risk control selection and, (4) risk control implementation and maintenance (Chua and Goh, 2005). Risk can be assessed and presented, using matrices, by estimating probabilities and consequences in a qualitative manner or, with quantitative values (Ayyub, 2003).

A risk matrix has been used to rank various risks in order of importance. The risk matrix is a table that includes several categories of probability, frequency, or likelihood for its rows (or columns) and several categories of severity, consequences, or impact for its columns (or rows) as shown in Table 3 (Zhou et al., 2011). Table 3 also demonstrates that risk will increase if either probability or severity rise, or both rise concurrently, and the majority of the safety measures will allocated to the dark-shaded cells in the upper right; high probability, high severity.

Table 3 Risk matrix of construction hazards

Level of Consequence	Description
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catastrophic

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Level of Frequency	Description
1	Never
2	Unlikely
3	Possible
4	Likely
5	Always

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Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

The significant rating of a risk (expected loss) that is found in the literature is shown in Eq.1 (Modarres, 2006):

$$Risk = Frequency \times Severity \qquad (1)$$

The rate of frequency and severity as well as the risk, in order of priority are revealed in Appendix A. Based on the results, the most critical hazards during construction of residential buildings are inappropriate use of ladders and hoists, poor inspection, struck by falling objects, materials and tools, and lack of edge protection respectively. On the contrary, the least critical hazards during construction of residential buildings are lack of innovative technology, improper cleaning and unusable materials, misplacing objects, and lack of protection in material storage respectively.

Hazards and risks across each activity

An expert panel group, including 21 safety officers and safety managers was interviewed in Malaysia in May 2011, to explore the potential relationship between construction hazards and activities. The relationship between the construction hazards of residential buildings and construction activities was identified from the results of the interview. For example, it was determined that stepping or striking against objects, limitation of working area, collapse of temporary structure, and inappropriate use of ladders and hoists are some of the hazards related to the concrete reinforcing process.

There are many and various construction activities, but common construction activities are related to one or more of the following: a) earth working, b) reinforcing, c) concreting, d) form working, and e) masonry (Gregory and Simon, 2006) which are selected for this study. The risk level of the each construction activities is calculated by summation of the risk level of related construction safety hazards. The summation of the risk level of construction hazards related to each activity give the total risk level of the construction activity (Gangolells et al., 2010, Cheng et al., 2002) (see Formula 2). Table 4 reveals the risk level of these five construction activities. Based on the results, it was identified that the riskiest construction activity is form working (Risk Level= 282.1).

$$\text{Risk Level of each Activity} = \sum a_i^{*} \quad (2)$$

*a_i= risk level of each construction hazard

Table 4 Risk level of construction activities

Construction Activity	Risk Level	Rank
Form Working	282.10	1
Reinforcing	235.17	2
Earth Working	232.54	3
Concreting	174.42	4
Masonry	166.67	5

Development of ASPP (Phase 2)

An algorithm was implemented in a computer program using Visual Basic for Application® (VBA) to design and develop the ASPP. It uses Microsoft Excel® as a database and Microsoft Project® as a source of schedule. Since contractors are the lightest users of BIM (Azhar, 2011), especially in developing countries (Mohd-Nor et al., 2009), this study did not integrate BIM with the selected project planning software. Microsoft Project®, which is widely used for project planning is selected to develop the ASPP (Bansal and Pal, 2009, Dave et al., 2010). The details of the ASPP development are discussed subsequently.

The ASPP development consists of three main phases: input, procedure, and output. The input used to develop the ASPP contains four databases: Risk Assessment, Construction Activities, Safety Regulations and Hazards (Figure 2). Risk Assessment database includes the risk rate for the most common hazards in residential buildings, including their frequency and severity. Using the risk assessment database, the project management team can be aware of the most dangerous hazard during each construction activity. Construction Activity database is based on the common construction activities. Safety Regulations database contains the essential safety regulations which was extracted from OSHA (Hu and Zhang, 2011). These regulations identify hazardous conditions as well as proper protective measures, e.g., "No worker is permitted underneath loads handled by lifting or digging equipment". Hazards database is required to determine the most critical safety hazards.

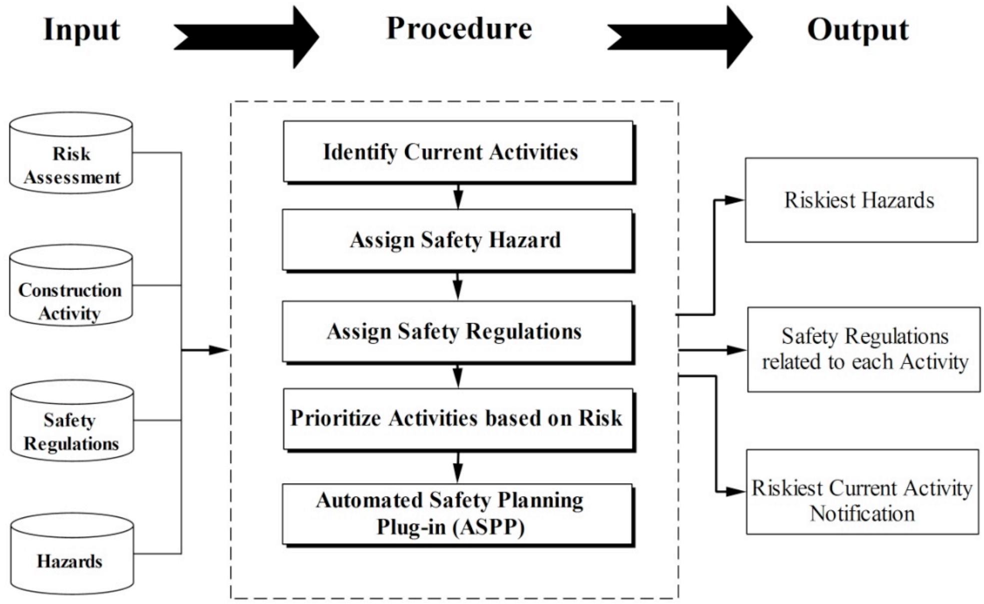

Figure 2 Schematic model of the automated safety-planning plug-in (ASPP)

The simplified algorithm of the ASPP is shown in Figure 3. The main programming procedure looks for the current activities, which are listed in the Construction Activity database. If the activity exists, related construction hazards and safety regulations will be assigned from the Hazards and Safety Regulation databases. Then, using the risk assessment database, the hazards will be prioritized based on their risk levels. Finally, after finding all current activities, the activities will be compared with each other to be ranked in order of their risks. This means that the most risky activity will be listed first, while the least risky activity will be listed last.

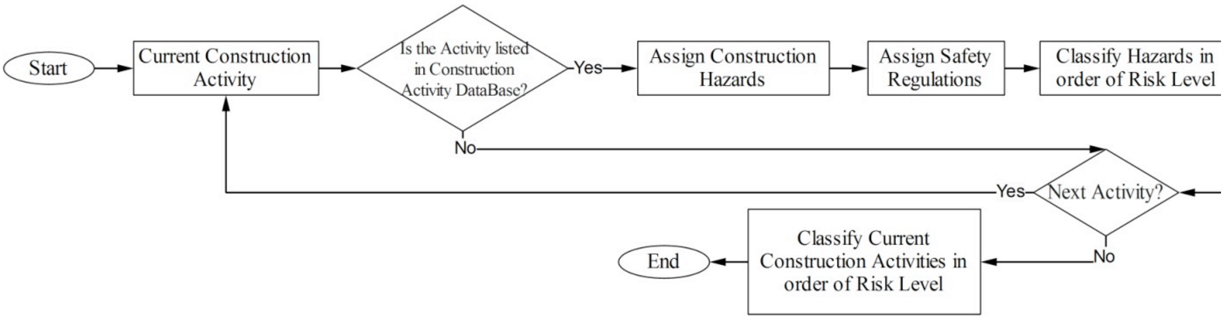

Figure 3 Algorithm of the ASPP

It is important for project managers to have a real time warning report about the most common hazards and safety regulations of current construction activities. The output of the ASPP is a report including start date, finish date, hazards, and safety requirements of current construction activities. The hazards are prioritized in order of risk levels so that the managers would be aware of critical hazards. Moreover, the report recommends comprehensive information about safety regulations related to current activities. This attribute helps the project management team to be aware of which protective measures should be considered for the current activities so as to mitigate probable accidents.

The ASPP has an automatic mode and a manual mode. In automatic mode, the ASPP automatically makes the safety report, consisting of hazards and recommended safety regulations related to daily activities. This mode will be useful, especially for novice project/safety managers for becoming aware of current hazards and high-risk activities on sites. In the manual mode, the operators can customize the report by selecting different hazards and safety indicators. This mode will provide the experienced user the ability to choose their preferred safety indicator. For example, one of the protective measures during excavation is 'the water removal equipment and operations should be monitored by a competent person to ensure proper operation'. If a site is located in a place with no probability of water accumulation, expert users might ignore this safety measure based on their knowledge.

Implementation and Evaluation of ASPP- A Case Study (Phase 3)

The construction of two blocks of five-story residential apartments located inside the campus of Universiti Teknologi Malaysia in Malaysia was used as a case study. Figure 4 displays the location map of the case study project. The duration of the project was 2 years and 7 months. The number of employees of the project was an average of 120.

Figure 4 The location map of the project job site

A site manager and a safety manager, who had more than 10 years of experience in construction safety and about four years of experience in Microsoft Project® use, were participated in evaluating the ASPP. In the first stage of the evaluation, a meeting was held with the site manager and safety manager to describe the ASPP and provide instruction of the automatic mode and manual mode. Users need to select their preferred mode in the first step of using the ASPP. The automatic mode is recommended to less experienced managers, because they just need to click on ‘Automatic Mode’ (step 1-Figure 5), then click ‘Make Report’ (step 2-Figure 5) to access the safety report automatically. By contrast, the Manual model is designed to enable experienced managers to manipulate the schedule if a task requires specific attention regarding safety. Managers can browse tasks on the schedule (Step 2- Figure 6), search the database looking for a specific safety regulation (Step 3- Figure 6), then based on the results obtained (Step 4- Figure 6), select an appropriate safety regulation and assign it to the task (Step 5- Figure 6). The ASSP creates a ‘Safety’ column in Microsoft project® and saves all of the assigned regulations.

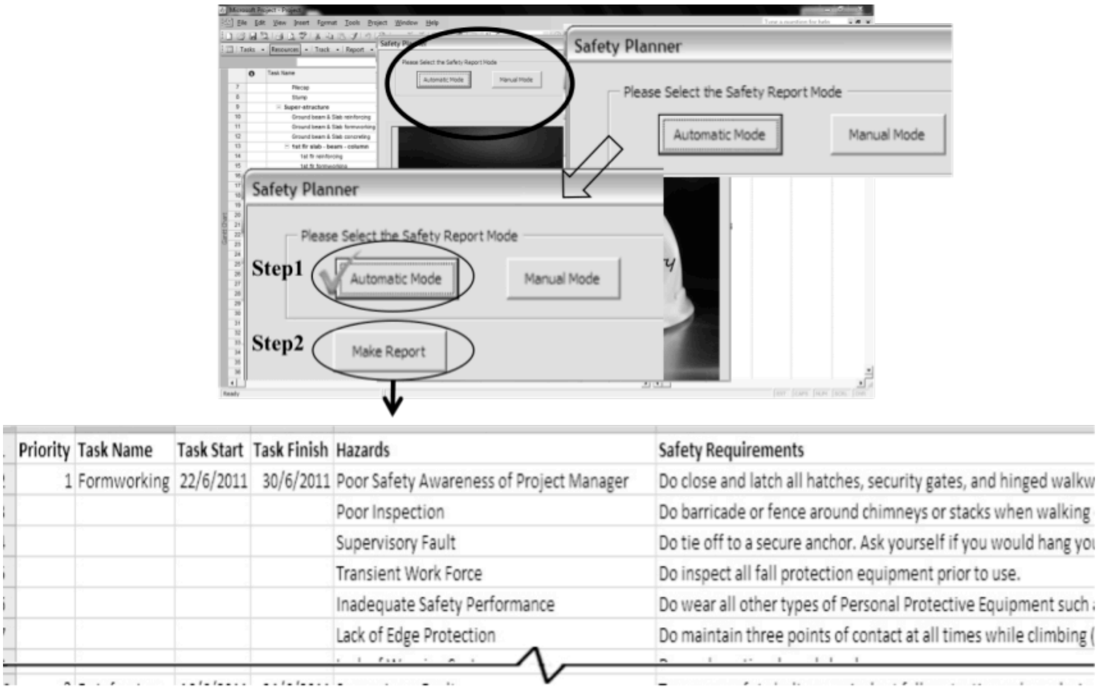

Figure 5 Interface of the ASPP- Automatic Mode

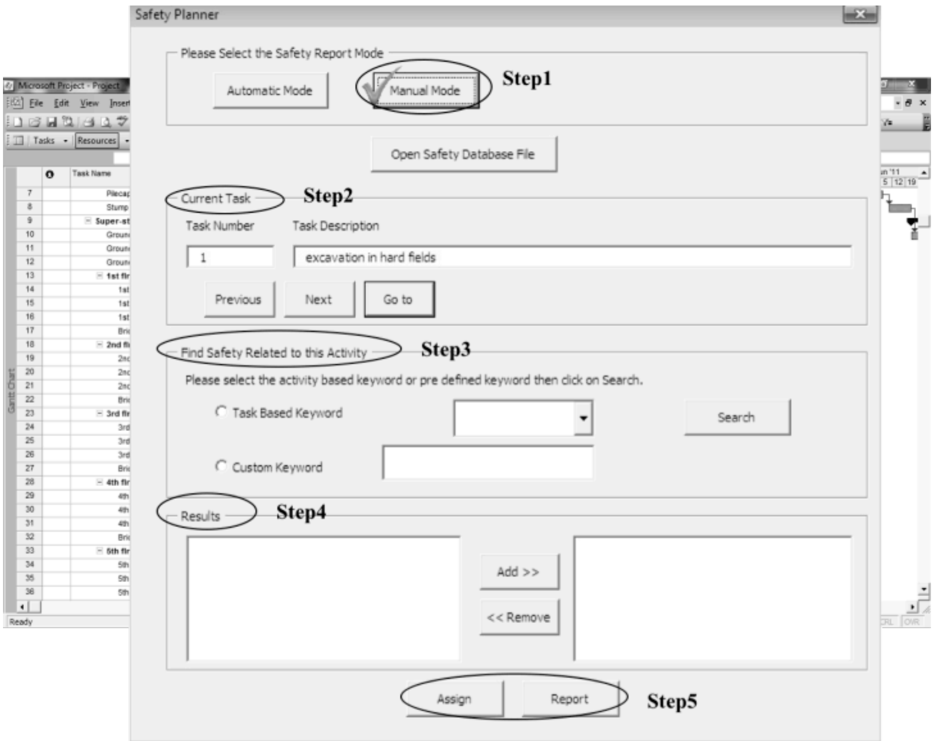

Figure 6 Interface of the ASPP- Manual Mode

The ASPP was used in the project for three months, from July to September 2011. At the end of the implementation of the ASPP, the users were requested to express their assessment regarding the ease-of-use and the usefulness of the ASPP as a safety planning tool. An unstructured interview with ASPP users (site manager and safety manager) was carried out to acquire users' feedback on ASPP application in their project. It was found that ASPP is able to help both site and safety managers to deliver required safety precautions to all personnel. For example, in the studied construction project, the safety manager has clarified the current hazards and safety measures of the daily construction activities for workers in toolbox and safety meetings. They discussed the probable hazards and required safety measures of current activities, which motivated workers to precisely act in accordance with the safety measures. Another expected benefit is that the user interface of the ASPP is easy to understand and users do not need specific knowledge on safety so that the ASPP can be used not only by safety managers, but also by other construction practitioners. The users mentioned that using ASPP made it easy for them to ensure that the necessary safety measures were accomplished in the right sequence and any nonconformity was easily found and corrected. In addition, the ASPP integrates the safety components (hazards and protective measures) with the project's schedule (construction activities) which has two advantages: a) Hazards of each activity can be recognized before starting actual work, b) Safety measures to be considered in the daily construction activities can be easily selected. Moreover, the safety-monitoring task is simplified when using the report from the ASPP to compare with actual safety performance on site. The integration of the construction schedule with hazards and safety measures created a clear and mutual understanding among the project team. Hazard identification and safety measures could be automatically or manually extracted. The users stated that they were able to customize the reports based on their requirements and priority. They could then consider necessary safety measures and coordinated with workers or other practitioners in advance. Finally, the ASPP provides the risk level of current construction activities so that it is possible to prevent probable accidents by paying more attention to the riskiest activity.

CONCLUSION

This research developed and tested an automated safety planning plug-in for safety management that incorporates safety measures into the project planning process. To do so, first this study investigated the most common construction safety hazards of residential buildings in order of their risk level. The results support the literature illustrating inappropriate use of ladders and hoists, poor inspection, struck by falling objects, materials and tools, and lack of edge protection are the riskiest construction hazards. Also, lack of innovative technology, improper cleaning and unusable materials, misplacing objects, and lack of protection in material storage were defined as the least critical hazards. In addition, summation of risk level of different construction hazards related to each activity illustrated that form working is the riskiest construction activity compared to others.

The risk assessment results were used to develop an automated safety planning plug-in (ASPP). The ASPP helps with reporting the riskiest activity at a site as well as the hazards and safety regulations associated with scheduled activities. It provides reports that make management teams aware of the main hazards and required protective measures; thus, the possibility of overlooking these hazards and the required safety regulations will be mitigated. The ASPP helps with easily identifying the potential hazards on construction sites in order to address them before starting the construction activities. The ASPP also can be used as a useful tool to assist designers in identifying hazards and integrate safety measures in the design stage. The developed plug-in was tested on site in an ongoing project in Malaysia. The results of the evaluation indicated that the outputs of the ASPP are accurate and also helpful to increase the project mangers' knowledge and awareness. It informs management teams what, when and where the accidents could happen and how to prevent these probable accidents, so they were able to consider and prepare safety measures before that work is actually executed.

The contribution of this study is to develop and test a prototype to integrate construction schedules with construction safety databases: construction safety hazards databases, risk assessment databases, and construction safety measure databases. Although the ASPP can be integrated to any construction schedule, the developed databases are limited to residential construction projects. This study could be a platform for developing automated safety planning systems that can be used widely in construction projects. Future studies need to investigate the risks and hazards related to different construction projects such as high-rise buildings and commercial buildings. In addition, these databases cover five common construction activities such as earth working, reinforcing, concreting, form working, and masonry. Future research will investigate additional construction activities and related safety hazards as well as applicable safety regulations in order to design comprehensive safety planning and monitoring systems.

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Appendix 1

Evaluation of risks related to causes of construction accidents

[a]FOC, Frequency of Occurring

Hazards	FOC[a]	SD[b] (FOC)	SEV[c]	SD (SEV)	Risk Level	Priority
Inappropriate use of Ladders and Hoists	2.92	0.95	3.62	0.94	10.57	Priority 1
Poor Inspection	2.63	1.00	3.44	1.05	9.05	Priority 2
Struck by Falling Objects, Materials and Tools	2.57	0.97	3.49	1.09	8.97	Priority 3
Lack of Edge Protection	2.45	1.00	3.66	1.16	8.95	Priority 4
Unsafe Position or Posture	2.76	0.96	3.18	0.88	8.79	Priority 5
Stepping or Striking against Objects	2.59	0.93	3.27	0.90	8.46	Priority 6
Hole and Edge	2.45	0.86	3.44	0.90	8.42	Priority 7
Lack of Warning System	2.56	1.02	3.27	1.06	8.37	Priority 8
Overexertion or Strenuous Movement	2.74	0.66	3.05	0.85	8.34	Priority 9
Used Defective Tools or Equipment	2.48	0.89	3.34	0.97	8.28	Priority 10
Slippery and Muddy Work Surface	2.55	1.07	3.24	0.84	8.27	Priority 11
Excessive Overtime Work	2.70	1.03	2.97	0.89	8.02	Priority 12
Failure to Secure Materials during Hauling or Lifting	2.35	1.03	3.40	0.96	7.98	Priority 13
Collapse of Temporary Structure	1.92	0.97	4.08	0.92	7.84	Priority 14
Physical and Emotional Stress	2.66	0.98	2.89	0.94	7.68	Priority 15
Operating Equipment Without Authority	2.31	0.99	3.30	0.91	7.64	Priority 16
Mechanical Failure of Machinery	2.27	0.88	3.36	0.97	7.63	Priority 17
Lack of Certain abilities	2.52	0.90	3.02	0.86	7.62	Priority 18
Excessive Noise	2.60	1.03	2.88	1.02	7.49	Priority 19
Unsafe Facilities and Equipment	2.25	0.98	3.30	1.02	7.43	Priority 20
Limitation of Working Area	2.47	0.85	2.89	0.99	7.13	Priority 21
Lack of Protection in Material Transportation	2.29	0.97	3.06	0.83	7.00	Priority 22
Lose of Balance	2.22	0.89	3.15	0.99	7.00	Priority 23
Transient Work Force	2.51	0.90	2.78	1.05	6.98	Priority 24
Poor Illumination	2.30	0.99	3.00	0.95	6.89	Priority 25
Poor ventilation	2.13	1.05	3.16	0.98	6.75	Priority 26
Substandard Structure or parts of Structure	2.08	0.94	3.24	0.99	6.72	Priority 27
Lack of Protection in Material Storage	2.29	0.93	2.81	0.92	6.45	Priority 28
Misplacing Objects	2.43	0.79	2.62	0.93	6.37	Priority 29
Improper Cleaning and Unusable Materials	2.32	0.94	2.74	0.93	6.35	Priority 30
Lack of Innovative Technology	2.34	1.04	2.65	0.94	6.21	Priority 31

[b]SD, Standards Deviation
[c]SEV, Severity of the effects of accident or consequences

Appendix 2

Questionnaire on identifying hazards and risks in construction sites

The aim of this research is to investigate hazards and risks which are involved in construction industry. The objective of this study is to identify which risk factors are caused the most injuries in construction sites.
All responses will be kept STRICTLY CONFIDENTIAL and exclusively for academic use. Only summaries will be publicized. Your contribution towards this study is greatly appreciated as it will significantly add to the value of this research.

1. Please state your years of experiences in safety as a team member or leader.
..... <=5 years
…. 5-10 years
…. 10-15 years
…. 15-20 years
…. Above 20 years

2. Please indicate average of individuals that are employed by your firm or organization.
…. Less than 50
…. 50-99
…. 100-249
…. 250-499
…. 500-999
…. More than 1000

3. Please indicate average annual revenue for your firm.

…. Less than $1 Million (M)
…. $1 M to 9.9 M
…. $10 M to 49.9 M
…. $50 M to 99 M
…. $100 M to 499 M
…. $500 M to $999 M
…. $1 Billion or more

4. Please indicate the frequency and severity of each risk and hazard in construction site based on your experience.
Frequency Section:
1 = Never, 2 = Seldom, 3 = Often, 4 = Almost, 5 = Always

Severity Section:
1 = not Severe, 2 = Less Severe, 3 = quite Severe, 4 = very Severe, 5 = absolutely Severe

Safety Hazards	Frequency					Severity				
Inappropriate use of Ladders and Hoists	1	2	3	4	5	1	2	3	4	5
Poor Inspection	1	2	3	4	5	1	2	3	4	5
Struck by Falling Objects, Materials and Tools	1	2	3	4	5	1	2	3	4	5
Lack of Edge Protection	1	2	3	4	5	1	2	3	4	5
Unsafe Position or Posture	1	2	3	4	5	1	2	3	4	5
Stepping or Striking against Objects	1	2	3	4	5	1	2	3	4	5
Hole and Edge	1	2	3	4	5	1	2	3	4	5
Lack of Warning System	1	2	3	4	5	1	2	3	4	5
Overexertion or Strenuous Movement	1	2	3	4	5	1	2	3	4	5
Used Defective Tools or Equipment	1	2	3	4	5	1	2	3	4	5
Slippery and Muddy Work Surface	1	2	3	4	5	1	2	3	4	5
Excessive Overtime Work	1	2	3	4	5	1	2	3	4	5
Failure to Secure Materials during Hauling or Lifting	1	2	3	4	5	1	2	3	4	5
Collapse of Temporary Structure	1	2	3	4	5	1	2	3	4	5
Physical and Emotional Stress	1	2	3	4	5	1	2	3	4	5
Operating Equipment Without Authority	1	2	3	4	5	1	2	3	4	5
Mechanical Failure of Machinery	1	2	3	4	5	1	2	3	4	5
Lack of Certain abilities	1	2	3	4	5	1	2	3	4	5
Excessive Noise	1	2	3	4	5	1	2	3	4	5
Unsafe Facilities and Equipment	1	2	3	4	5	1	2	3	4	5
Limitation of Working Area	1	2	3	4	5	1	2	3	4	5
Lack of Protection in Material Transportation	1	2	3	4	5	1	2	3	4	5
Lose of Balance	1	2	3	4	5	1	2	3	4	5
Transient Work Force	1	2	3	4	5	1	2	3	4	5
Poor Illumination	1	2	3	4	5	1	2	3	4	5
Poor ventilation	1	2	3	4	5	1	2	3	4	5
Substandard Structure or parts of Structure	1	2	3	4	5	1	2	3	4	5
Lack of Protection in Material Storage	1	2	3	4	5	1	2	3	4	5
Misplacing Objects	1	2	3	4	5	1	2	3	4	5
Improper Cleaning and Unusable Materials	1	2	3	4	5	1	2	3	4	5
Lack of Innovative Technology	1	2	3	4	5	1	2	3	4	5