Safety Hazards Identification of Construction Site Layout Based on Geographic Information System (GIS)

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Abstract

— In the world’s gross domestic product, the construction industry accounts for about 10% and plays a significant role in the eastern and western economies. Hectic places, unique characteristics, and an ever-changing work environment and its dynamic nature make construction sites challenging to predict before construction or during the life cycle project. The physical and psychological problems of construction workers caused by the construction site’s poor safety, economically, significantly affect the project with a significant increase in costs. This study aims to identify occupational safety hazards by proposing occupational safety hazards in predicting worker safety hazards at construction sites. In this research, GIS is used to present the relationship between temporary facilities and safety issues at construction sites to improve the accuracy of identifying work accidents. The data collection stages were carried out through a location survey, geographic spatial, and interviews by SHE managers on a high-rise building construction project. The site layout's dynamic safety assessment is a step in GIS development in obtaining the safety zone accuracy around the temporary construction facility. It was found that there is a combination of GIS capabilities in the accuracy of site layout, which can significantly increase safety at the construction site to obtain recommendations for safety measures and minimize the occurrence of work accident fatalities through preventive actions.

Keywords

— safety hazards; site layout construction; geographic information system.

I. INTRODUCTION

Construction remains to be the most dangerous industry in terms of the total number of deaths [1]. In 2005, the construction industry experienced 1243 total deaths or 21% of all work-related fatalities in the United States [2]. In 2015 there were approximately 4,836 workers who died due to injuries from work. The projected number is the highest since 2008 and has increased from 2014. The number of work accidents has increased from year to year, with a trend of 5% [3]. Planning in construction projects becomes very difficult due to uncertainty and high complexity [4]. The increased likelihood of accidents due to the disorderly placement of construction resources emphasizes site layout planning [5]. Construction methods, scale and type of project, project site conditions, and operational safety management standards are a set of several factors that influence the safety of a construction project [6]. The availability of a working environment at a safe construction site and applying a safety management system to minimize injuries have been carried out by several construction companies throughout the world [7]. However, in 2013 it increased the rate of fatality to 2.9 times compared to other industries. This rate can be seen from the decrease in construction safety improvement [8].

Economic, safety, and other aspects are significantly affected by the importance of the construction site layout. The emergence of unexpected costs is one result of the hazards of safety at the construction site. In addition to the resources of money, duration of time, allocation of material, construction workers, and the equipment, the construction site space is as important as these resources [9]. The lack of labor efficiency, repositioning temporary facilities is a result of spend due time by improper site layout planning [10]. These reasons make it necessary to synergize all existing facilities, topography, environment so that construction planning is one unit and not separate [11]. The increased safety of the construction site’s site layout will precisely affect the construction of site layout, contributing significantly to construction safety, cost reduction, and material travel distance [12], [33]. Consideration of the application of the construction layout and to organize the construction of sites has not been based on previous studies. The importance of developing appropriate guidelines in the first stages of the construction life cycle project can avoid hazards from death [13].

The application of procedures and equipment arrangements in the workplace is determined before the
same conditions during the under-construction project.

for preventive actions in the future and not to repeat the

System (GIS). Modelling construction sites and integrating

construction and propose a 3D model of construction safety

safety databases in 3D space can provide evaluation actions

to analyze risky work zones using Geographic Information

data and safety knowledge, temporal information, spatial

advantages in the spatiotemporal analysis. By combining

has been done in previous studies and makes GIS's

[11],[35],[36]. Optimization of material layout in planning

excess that can reduce the occurrence of work accidents

Emphasis on topographic information on the use of GIS is an

layout of dynamic construction materials [30],[31],[32].

specific spatial information can formulate a 4D model of

Intense spatial analysis data such as track width, lattice

is referred to as Geographic Information Systems (GIS) [26].

storage, display, geographic data input in computer systems

geometric and topological constraints that challenge the

optimizing the performance improvement of tunnel utilities

project layout [27], integration of material layout planning in

spatial properties in GIS help in site layout planning for

the development of based cost estimation systems [28],

feasibility of construction planning significantly influences

planning, and others [11], [21], [22], [34]. The spatial

analysis which includes the planning of safety measures as

route access, topographic location, thermal comfort, and

has limitations in factor analysis of environmental conditions,

problems [19],[20]. The use of BIM and 4-dimensional CAD

MoveSchedule, fuzzy, and Building Information Modelling

several previous studies [15]-[18]. Application and

in meeting the needs of storage space, fabrication, and

predefined of facilities in the space available on the site are

operational phase-in safety. Trending topics that analyze the

problems based on knowledge systems as well as CAD

development of models in solving site layout of construction

smoothness in the implementation of the method.

The GIS discussion on temporal integration and site-

potential additional information that can then be developed

into activities for all types of projects. This will be very

training can be prepared in advance at the project site.

the hazards caused by other work activities. Dynamic control

activities, including construction methods, work calendar

of the schedule can be applied so that periodic and proactive

visualizations of safety scores provide an approximation of

represent work zones virtually. Temporal and spatial

The integration provides space in estimating 3D models to

high enough. The relationship between busy activities and

becomes very crucial when the complexity of the activities is

quantification results. Integrated temporal information

hazards are identified can be prioritized from the

and safety measures that need to be implemented when

accumulation of the same activity quantified to estimate risk,

spatial secondary data collected related geographic locations

file as a source of additional information. Spatial and non-

Regular updates and extensions to the safety documentation

references that have relevance to the activities carried out.

documentation database, including codes and regulatory

Approval of new locations for site layout can be

considered. The database of the past site layout investigation

has been made in providing solutions to site layout

Material and Method

The analysis of the factors that impress the risk of

Fig. 2 shows the safety score in the work zone by

stakeholders in making effective decisions on work safety.

Fig. 1

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II.

Safety score estimation process (Choe [22])
The analyzed building area includes basement floors 1 to 3 under construction at the time this research was conducted. The construction project under review is an apartment building that has 35 tasks planned in the area approximately 58,582.36 m². This project consists of 38 floors for occupancy, 4 podium floors, and 3 floors of the basement area. The construct's scope is preparation work, excavation, bore pile kingpost, steel beam, mass concrete, and the residential floors 1 to 3, in the work breakdown structure of the construction work of the construction project to structure work such as capping beam, inclinometer, drainage works. The second group part is an activity related to preparation works, including the excavation, beam, and slab concrete. After activity safety evaluation phase, identification and analysis of each activity's safety risks are carried out in Table 1. 4 top jobs are ranked as the most dangerous work risks, and top-down risk analysis takes by project hazard identification and risk evaluation phase, identification and analysis of each activity's safety risks are carried out in Table 1. 4 top jobs are ranked as the most dangerous work risks, and top-down risk analysis takes by project hazard identification and risk evaluation phase, identification and analysis of each activity's safety risks are carried out in Table 1. 4 top jobs are ranked as the most dangerous work risks, and top-down risk analysis takes by project hazard identification and risk evaluation phase, identification and analysis of each activity's safety risks are carried out in Table 1. 4 top jobs are ranked as the most dangerous work risks, and top-down risk analysis takes by project.
| Task               | Hazard Type                                                                 | Risk Severity | Likelihood | Location | Risk Rating |
|-------------------|------------------------------------------------------------------------------|---------------|------------|----------|-------------|
| Preparation Work  | Lack of skills in recognizing and awareness of the hazards of the weather and the environment it is exposed to | 5             | 3          | B1, B2, B3, 1st FL, 2nd FL, 3rd FL | 15           |
| Inclinometer Work | Ground movement, Landslide, collapse of structure                           | 5             | 3          | B1, B2, B3, 1st FL, 2nd FL, 3rd FL | 15           |
| Kingpost Top-Down construction | Installation of tools and work material kingpost, falling loads from cranes, falling objects, fatigue | 5             | 4          | B1, B2, B3 | 20           |
| Kingpost Top-Down construction | The dangers of illness due to exposure to very extreme temperatures include dehydration, exposure to excessive light and temperature, accidents that result in an impact on the head, and all parts of the body including cuts, wounds with translucent body parts, injured eyes, wounds originating from impact, as well as the impact of safety hazards that increase significantly over a long period of time such as noise and dust exposure. | 5             | 4          | B1, B2, B3 | 20           |
| Trenching and excavation work | Basement excavation and unsafe excavation soil disposal, collapse cranes, landslides, gas inhalation, falling objects, crash by excavators, property damage, the downfall of dump trucks | 5             | 3          | B1, B2, B3 | 15           |
| Shear wall work | Shear wall erection inappropriate method, Shear wall falls, falls from height, tower crane sling breaks up, noise | 5             | 3          | B1, B2, B3 | 15           |
| Shear wall work | Shear wall casting without working method, Crash bucket concrete, falling into the shear wall area, falling concrete pile from top floor | 5             | 5          | B1, B2, B3 | 25           |
| Beam and Slab | Using of damage or unproperly scaffold | 5             | 3          | B1, B2, B3 | 15           |
| Beam and Slab | Lack of or wrong design of rebar case, Scratched or cut but sharp edges, Rebar case falls or rolls over, Hazard of pinched by materials, Rebar Case collapse | 5             | 3          | B1, B2, B3 | 15           |
| Beam and Slab | casting floors without work shifts, Dropped load due to failure of lifting equipment components or failure of lifting gear / accessories, Noise level exposure | 5             | 3          | B1, B2, B3, 1st FL, 2nd FL, 3rd FL | 15           |
| Beam and Slab | use tools for access and platforms that are not standard | 5             | 3          | B1, B2, B3 | 15           |
Fig. 4 Model of high rise building along with its surrounding developed in ArcGIS and specific analysis in the zone of basement 3, basement 2, basement 1, 1st floor, 2nd floor, and 3rd floor.

Fig. 5 Work zone risk was classified
The importance of proactive analysis is an obstacle in the tools in predicting the location of activities and time based field by SHE managers. Lack of anticipatory actions, limited framework and guidelines are not legally owned consistently.

This step is done because the development of a safety plan. This step is done in a systematic step by step manner assists SHE managers in starting some activities by repeating scheduling to ensure a safe work area during construction.

The analysis of the safety risks of activities carried out in the construction sector so that the project can fulfilling the problems in the field provides an overview of hazards affecting workers on site. The animation findings also provide steps to start some activities by repeating scheduling to ensure a safe work area during construction.

In the construction planning, geographically, the project allocation of all activities and a zoning plan is needed as applied systematically optimally. Running software programs is a challenge for SHE managers and sustained preventive measures and safety inspections were available areas. Guidelines for effective and safe vehicle access points, implementation of handles, guardrails, warning boards and falling protection measures to protect workers on site. The animation findings also provide steps to start some activities by repeating scheduling to ensure a safe work area during construction.

In safety, planning identified the most dangerous jobs are in the construction sector so that the project can fulfill the requirements. In the top-down kingpost job is the most dangerous job with the existing job positions on each floor. This job is ranked the highest because it is the most at risk of experiencing a collision from falling objects from a height. This is a heavy equipment as well as dust exposure is a challenge in exposure to toxic gases, landslides, and falling objects from a height. This work has a possible hazard, namely the falling of the concrete bouquet during the lifting process from the tower crane, falling objects from a height. This job is ranked the highest because it is the most at risk of experiencing a collision from falling objects from a height.

Activities include susceptibility to falling objects from a height. This job is ranked the highest because it is the most at risk of experiencing a collision from falling objects from a height. This is a heavy equipment as well as dust exposure is a challenge in exposure to toxic gases, landslides, and falling objects from a height. In the top-down kingpost job is the most dangerous job with the existing job positions on each floor. This job is ranked the highest because it is the most at risk of experiencing a collision from falling objects from a height. This is a construction with collaborative and interactive GIS-based topology. GIS development helps in identifying hazardous zones at project sites.

The results of the analysis summarize some of the potential for fatalities. The use of methods that can only predict safety risks in the long-term. The availability of color visualization in color indicators which are classified into three categories, namely green for jobs with a relatively low level of risk, the medium risk is visualized in blue, and for jobs that have the most dangerous and critical zones that occur, and the location of hazardous zones have not been analyzed. The next job with a hazard with a source of danger due to the occurrence, fatigue, and stress. The excavation work is the rebar cuts that do not comply with the provisions of the installation of rebar on edges where there are no guardrails. Beam and column construction are ranked next as a heavy equipment as well as dust exposure is a challenge in exposure to toxic gases, landslides, and falling objects from a height. This work has a possible hazard, namely the falling of the concrete bouquet during the lifting process from the tower crane, falling objects from a height. This job is ranked the highest because it is the most at risk of experiencing a collision from falling objects from a height.

This research is a form of maintaining spatial and non-spatial data from construction sites. The integration of the analysis data provides positive warning system for construction players to safely use all access points, implementation of handles, guardrails, warning boards and falling protection measures to protect workers on site. The animation findings also provide steps to start some activities by repeating scheduling to ensure a safe work area during construction.

In the construction period gives the SHE manager an advantage over the long term so that adequate efforts based on experience and knowledge. The reason for construction work in dangerous zone conditions for shear wall concrete activity. The potential for fatalities. The use of methods that can only predict safety risks in the long-term. The availability of color visualization in color indicators which are classified into three categories, namely green for jobs with a relatively low level of risk, the medium risk is visualized in blue, and for jobs that have the most dangerous and critical zones that occur, and the location of hazardous zones have not been analyzed. The next job with a hazard with a source of danger due to the occurrence, fatigue, and stress. The excavation work is the rebar cuts that do not comply with the provisions of the installation of rebar on edges where there are no guardrails. Beam and column construction are ranked next as a heavy equipment as well as dust exposure is a challenge in exposure to toxic gases, landslides, and falling objects from a height. This work has a possible hazard, namely the falling of the concrete bouquet during the lifting process from the tower crane, falling objects from a height. This job is ranked the highest because it is the most at risk of experiencing a collision from falling objects from a height.

The suggestions in this research analysis can provide an immediate warning system for construction players to safely use all access points, implementation of handles, guardrails, warning boards and falling protection measures to protect workers on site. The animation findings also provide steps to start some activities by repeating scheduling to ensure a safe work area during construction.
described in red. Validation of approaches and large-scale testing with different types of projects is recommended for future research by using more specific safety risk data which is very helpful in improving safety and risk ranking, thus minimizing the occurrence of fatalities.

REFERENCES

[1] M. Behm, “Linking construction fatalities to the design for construction safety concept,” Saf. Sci., vol. 43, no. 8, pp. 589–611, 2005.

[2] M. Shin, H. S. Lee, M. Park, M. Moon, and S. Han, “A system dynamics approach for modeling construction workers’ safety attitudes and behaviors,” Accid. Anal. Prev., vol. 68, pp. 95–105, 2014.

[3] D. Sarasanty, T. J. Wahyu Adi, and I. P. A. Wiguna, “Probabilistic Model for Predicting Construction Worker Accident Based on Bayesian Belief Networks,” IPIEX. J. Proc. Ser., vol. 3, no. 6, 2017.

[4] V. K. Bansal, “Integrated CAD and GIS-Based Framework to Support Construction Planning: Case Study,” J. Archit. Eng., vol. 23, no. 3, pp. 1–13, 2017.

[5] X. Ning, J. Qi, and C. Wu, “A quantitative safety risk assessment model for construction site layout planning,” Saf. Sci., vol. 104, no. October 2017, pp. 246–259, 2018.

[6] J. W. Seo and H. H. Choi, “Risk-based safety impact assessment methodology for underground construction projects in Korea,” J. Constr. Eng. Manag., vol. 134, no. 1, pp. 72–81, 2008.

[7] R. M. Choudhry, D. Fang, and S. M. Ahmed, “Safety management in construction: Best practices in Hong Kong,” J. Prof. Issues Eng. Pract., vol. 134, no. 1, pp. 20–32, 2008.

[8] M. Esmaeili, B. Hallowell, “Diffusion of Safety Innovations in the Construction Industry,” J. Constr. Eng. Manag., vol. 138, no. January, pp. 51–60, 2013.

[9] E. Hegazy, Tarek; Elbelalti, “Eovosite: Evolution-Based Model For Site Layout Planning,” J. Comput. Civ. Eng., vol. 13, pp. 198–206, 1999.

[10] X. Su, A. R. Andoh, H. Cai, J. Pan, A. Kandil, and H. M. Said, “GIS-based dynamic construction site material layout evaluation for building renovation projects,” Autom. Constr., vol. 27, pp. 40–49, 2012.

[11] U. Isikdag, J. Underwood, and G. Aoudad, “An investigation into the applicability of building information models in geospatial environment in support of site selection and fire response management processes,” Adv. Eng. Informatics, vol. 22, no. 4, pp. 504–519, 2008.

[12] K. El-Rayes and A. Khulafallah, “Trade-off between safety and cost in planning construction site layouts,” J. Constr. Eng. Manag., vol. 131, no. 11, pp. 1186–1195, 2005.

[13] C. Anumba and G. Bishop, “Importance of safety considerations in site layout and organization,” Can. J. Civ. Eng., vol. 24, no. 2, pp. 229–236, 1997.

[14] A. J. Khattak and H. Shamayleh, “Highway safety assessment through geographic information system-based data visualization,” J. Comput. Civ. Eng., vol. 19, no. 4, pp. 407–411, 2005.

[15] J. Gao, “Identification and resolution of work space conflicts in building construction,” J. Constr. Eng. Manag., vol. 128, no. 4, pp. 287–295, 2002.

[16] D. Reilly and V. Sanvido, “Patterns Of Construction-Space Use In Multistory Buildings By David R. Riley - and Victor E. Sanvido, 2 Associate Members , ASCE,” J. Constr. Eng. Manag., no. December, pp. 464–473, 1995.

[17] S. Razaviialavi and S. AboutaRizk, “Site Layout and Construction Plan Optimization Using an Integrated Genetic Algorithm Simulation Framework,” J. Comput. Civ. Eng., vol. 31, no. 4, pp. 1–10, 2017.

[18] M. Xu, Z. Mei, S. Luo, and Y. Tan, “Optimization algorithms for construction site layout planning: a systematic literature review,” Eng. Constr. Manag., 2020.

[19] F. Zhou, S. M. AboutaRizk, and H. Al-Battaineh, “Optimisation of construction site layout using a hybrid simulation-based system,” Simul. Model. Pract. Theory, vol. 17, no. 2, pp. 348–363, 2009.

[20] P. L. Le, T. M. Dao, and A. Chaabane, “BIM-based framework for temporary facility layout planning in construction site: A hybrid approach,” Constr. Innov., vol. 19, no. 3, pp. 424–464, 2019.

[21] X. Ning, J. Qi, C. Wu, and W. Wang, “Reducing noise pollution by planning construction site layout via a multi-objective optimization model,” J. Clean. Prod., vol. 222, pp. 218–230, 2019.

[22] X. Song, J. Xu, C. Shen, and F. Peña-Mora, “Conflict resolution-motivated strategy towards integrated construction site layout and material logistics planning: A bi-stakeholder perspective,” Autom. Constr., vol. 87, no. December 2017, pp. 138–157, 2018.

[23] T. H. Nguyen, A. A. Oloufa, and K. Nassar, “Algorithms for automated deduction of topological information,” Autom. Constr., vol. 14, no. 1, pp. 59–70, 2005.

[24] W. Jiang, Y. Zhou, L. Ding, C. Zhou, and X. Ning, “UAV-based 3D reconstruction for host site mapping and layout planning in petrochemical construction,” Autom. Constr., vol. 113, no. February, 2020.

[25] C. Wu, N. Li, and D. Fang, “Leadership improvement and its impact on workplace safety in construction projects: A conceptual model and action research,” Int. J. Proj. Manag., vol. 35, no. 8, pp. 1495–1511, 2017.

[26] P. C. Lee, Y. Wang, T. P. Lo, and D. Long, “An integrated system framework of building information modelling and geographical information system for utility tunnel maintenance management,” Tunn. Undergr. Sp. Technol., vol. 79, no. April, pp. 263–273, 2018.

[27] M. Y. Cheng and J. T. O’Connor, “Arcsite: Enhanced GIS for construction site layout,” J. Constr. Eng. Manag., vol. 132, no. 4, pp. 329–336, 1996.

[28] M. Y. Cheng and J. T. O’Connor, “Site layout of construction temporary facilities using an enhanced-geographic information system (GIS),” Autom. Constr., vol. 3, no. 1, pp. 11–19, 1994.

[29] X. Su and H. Cai, “Enabling Construction 4D Topological Analysis for Effective Construction Planning,” J. Comput. Civ. Eng., vol. 30, no. 1, pp. 1–10, 2016.

[30] S. Choe and F. Leite, “Construction safety planning: Site-specific temporal and spatial information integration,” Autom. Constr., vol. 84, no. August 2016, pp. 335–344, 2017.

[31] W. Yi, H. L.Chi, and S. Wang, “Mathematical programming models for construction site layout problems,” Autom. Constr., vol. 85, no. May 2017, pp. 241–248, 2018.

[32] K. Schwab, J. Teizer, and M. König, “Applying rule-based model-checking to construction site layout planning tasks,” Autom. Constr., vol. 97, no. October 2018, pp. 205–219, 2019.

[33] X. Liu, X. Wang, G. Wright, J. C. P. Cheng, X. Li, and R. Liu, “A state-of-the-art review on the integration of Building Information Modeling (BIM) and Geographic Information System (GIS),” ISPRS Int. J. Geo-Information, vol. 6, no. 2, pp. 1–21, 2017.

[34] C. W. Liu, T. H. Wu, M. H. Tsai, and S. C. Kang, “Image-based semantic construction reconstruction,” Autom. Constr., vol. 90, no. February, pp. 67–78, 2018.

[35] F. Sandrone and V. Labiouse, “A GIS based approach for analysing geological and operation conditions influence on road tunnels degradation,” Tunn. Undergr. Sp. Technol., vol. 66, no. November 2016, pp. 174–185, 2017.

[36] S. Yamamura, L. Fan, and Y. Suzuki, “Assessment of Urban Energy Performance through Integration of BIM and GIS for Smart City Planning,” Procedia Eng., vol. 180, pp. 1462–1472, 2017.