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A PROPOSED INITIAL FRAMEWORK OF ASRC SYSTEM FOR BIM-BASED PROJECTS IN MALAYSIA

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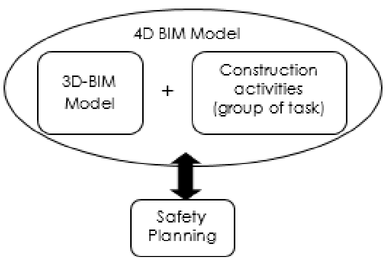
Graphical abstract



Abstract

Of late, Building Information Modelling (BIM) has been well established in the construction industry across the globe. Nevertheless, safety aspect is less contemplated when it comes to construction phase. Despite safety is one of the most decisive aspects in BIM development process, the model of Automated Safety Rule Checking (ASRC) system should be deployed at the early project stage to reduce the construction's hazard. Thus, the aim of this research are two folds; (1) to distinguish the models of ASRC system implemented in Finland, United States (US), Thailand and China and; (2) to propose an amalgamated initial framework of ASRC system for BIM-based projects in Malaysia. A descriptive survey was employed to large public and private construction organisations that involved in BIM-based projects. The data were analysed by using document analysis and content analysis techniques. Five significant fundamental components from the models were revealed in developing the initial framework of ASRC system. With the establishment of the framework, safety is going to be prime concern in near future, particularly in Malaysia BIM-based construction projects.

Keywords: Automated Safety Rule Checking (ASRC), Building Information Modelling (BIM), Malaysia

1.0 INTRODUCTION

Safety is vital in ensuring the successfulness of a construction project. It is necessary for a project to perceive on safety aspects (i.e., the building structure, worker's safety and safety of the publics) particularly at construction planning stage[1, 2, 3]. This is due to construction industry is inevitable from fatal and accident [3]. In-line with [2, 4, 5], most of the accidents and fatalities in construction industry are caused by falls, electrocutions, struck by object and caught-in/between the object. For instance, in 2013, more than half (57.7%) of the construction workers in United States (US) died due to these hazards (i.e., falls-36.5%, struck by objects-10.1%, electrocutions-8.6% and caught-in/between the object-2.5%)[5]. Likewise, 37.7% of fatalities in Malaysia encompass with falls, electrocutions, struck by object and caught-in/between the object were contributed by construction workers [6]. The statistics indicate that safety in construction industry remains as serious problem. The probable reason for the failure to reduce the numbers of such accident event could be due to separate planning management of project execution planning and safety planning [7, 8]. This separation could lead to inefficient work planning and supervision, lack of communication between project team, and lack of training and practices in safety culture [1,9,10].Over recent years, Building Information Modelling (BIM) has been established in construction industry to construct a better planning and management for a project development [11]. BIM technology is increasingly used abroad as an emerging technology to assist in conceiving, designing, constructing and operating the building [12]. Based on the study done by various researchers, it has been proven that 4D BIM model which is integrated with safety planning could assist in mitigating the safety hazard across project phases [2], [13], [14], [15]. Hence, the integration in a form of

Automated Safety Rule Checking (ASRC) system shall be used in diminishing the hazards as the project progresses. This is in-line with the definition stated by [15], ASRC system is *an integrated safety rule checking system based on 4D-model developed in planning stage to assist in construction project phase*.

Nevertheless, as has been asserted by [16], the ASRC system is yet to be incorporated in Malaysia BIM-based projects. Thus, this paper seeks to distinguish various model of ASRC system implemented in Finland, US, Thailand and China based on their detailed case-studies. Various significant fundamental components were abstracted from these models. Through a face-to face interview, data were collected and synthesised for the initial development of proposed framework of BIM-based ASRC system in Malaysia.

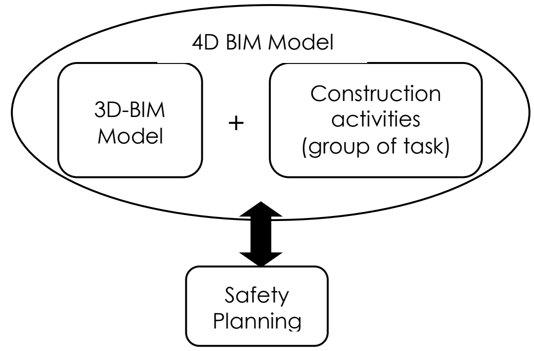


Figure 1 The preliminary concept of ASRC system [8]

2.0 CONCEPT AND IMPACT OF ASRC SYSTEM ON CONSTRUCTION SAFETY

Documentation of a construction project is vital for the fact that it could lead to inefficient work planning, cost overruns, adversarial behaviour, diminish reputation and declination in safety standard [17]. In-spite, BIM-based ASRC system is an anticipated platform in providing a means of information exchange for 4D design model and safety design between various stakeholders involved (i.e., designer, engineers, contractor and safety officer) [18], [19]. Chantawit and Hadikusumo stating that the preliminary *concept* of ASRC system is an integration between 3D BIM model and construction activities with the safety planning [8].

As shown in Figure 1, the integration of ASRC system is divided into two components: 1) 4D BIM model (a combination of 3D BIM model and construction activities) and 2) elements of safety planning (i.e., safety rules and hazard identification). Consequently, the impact from this integration shall be ascertained as an advanced safety checking method for hazard identification across project phases. This implies that, hazard which produced by the construction activities shall be analysed using 4D BIM model [21]. Manual safety checking generally follow four processes: 1) identify the sequences of construction by using construction schedule or Work Breakdown Structure (WBS); 2) identify the conditions that possibly lead to safety hazards; 3) plan corrective action to eliminate the detected potential hazards; and 4) insert these actions into the schedule[4], [19].

However, some constraints to follow this processes (i.e., lack of skill in identifying the hazards and difficult to simulate complex future safety conditions) suggest a more practical and simulation based method [7], [13], [22]. Hence, BIM-based ASRC system shall assist safety management by identifying and visualizing the potential hazards and hazard prevention tasks [4].

3.0 METHODOLOGY

This study commences with the spearhead of literature collection for the ASRC system models across the globe. The literature collection was analysed by using document analysis technique to distinguishing the models and abstract the fundamental components of each model. Five fundamental components were abstracted (i.e., formation of 4D building model (BIM); safety aspect; ASRC components; benefits derived from the system; and challenges in adopting the system). The second stage is to conduct a face-to-face semi-structured interview to both public and private construction organisations (see Table 1). The interview was conducted to four respondents (i.e., 3 respondents from public and 1 from private organisation). These respondents were selected since majority of them have more than 10 years working experience in the construction industry and have an average of 5 years involvement in BIM-based projects. This implies that, they are conversant in BIM except respondent 3. Although respondent 3 is not regarded as proficient in BIM, he was selected due to the long involvement in construction safety since 2000. The data from the interview were analysed by means of content analysis technique to propose an initial framework of ASRC system for BIM-based project in Malaysia.

Table 1 Respondent's information

Res.	Type of Organisation	Designation	Discipline	Years of Experience	
				Industry	BIM-Based Project(s)
R1	Public Organisation	Assistant Manager	Architect	10 years	5 years
R2	Public Organisation	Project Engineer	Engineer	9 years	4 years
R3	Public Organisation	Assistant Vice President	Safety and Health Manager	15 years	1 years
R4	Private Organisation	Design Executive	Modeller/ Designer	21 years	6 years

4.0 AN AMALGAMATED MODEL OF ASRC SYSTEM FROM FINLAND, US, THAILAND AND CHINA

Models of ASRC system has been gathered from various researchers in Finland, US, Thailand and China. These countries were chosen due to the rapid implementation of BIM and the benefits derived have been perceived by the project practitioners [23]. The models are case study-based research that already implementing ASRC system across their project phases. For instance, in Finland (i.e., office building in Helsinki, and industrial building in Eurajoki) [24], US (i.e., Recreation & Wellness Centre, Auburn University) [1], [2], Thailand (i.e., three-floor hotel) [14] and China (i.e., Wuhan Metro Line 2) [13]. The findings from document analysis and content analysis techniques are discussed in turn.

4.1 Findings- Document Analysis Technique

Table 2 shows the data gathered based on document analysis technique from Findland, US, Thailand and China. Five fundamental components in realising ASRC system across project phases have been gathered. These are: *(1) formation of 4D building model (BIM); (2) safety aspect; (3) ASRC components; (4) benefits derived from the system; and (5) challenges in adopting the system.* Each model is discussed in table 1 and the fundamental components from each model were singled out and summarised below for the development of initial framework BIM-based ASRC system in Malaysia.

Referring to Table 2, these four (4) countries, to a certain extent, are enjoying full benefits derived from BIM-based ASRC system. However, it has been examined that each of these models has its own strengths and weaknesses. Hence, the elements of each component were gathered, adopted and adapted to propose an initial framework of ASRC system for BIM-based projects in Malaysia.

As regards to the first component (i.e., formation of 4D building model), the integration of building design and construction planning are inevitable to develop 4D building model (BIM). This shall be executed with aid of construction sequences and activities (or known as Work Breakdown Structure- WBS). The formed 4D building model shall be fused together with safety aspect. From the models, four elements of safety are identified in the development of ASRC system. These are including: hazard identification, safety rule-based algorithm, safety rule checking process (i.e., rule of interpretation, model preparation, execution, checking reporting, and safety correction) and safety parameter (i.e., safety rules & regulation from safety organisations). The reasons to include safety aspects in ASRC system of BIM-based project for the fact that safety are not tolerable and to comply with regulatory compliances

Subsequently, ASRC components or the features are divided into three project phases (i.e., pre-construction phase, construction phase, and post construction phase). In pre-construction phase, a component which is the location of planned project (i.e., entrance or exit route) was identified. Followed by construction phase, 8 ASRC components including crane management plan, excavation risk management plan, safety visualisation of diaphragm wall, visualisation of earth-retaining wall, visualisation of vicinity components, fall protection plan (for floor, wall and roof), 4D visualisation of slab formwork with needed falling prevention and fall offset perimeter for column and beam construction are recognised. As for the post-construction phase, visualisation of wall demolition procedures has been implemented in Finland projects. This implies in total, 10 significant ASRC components are required to be deployed by those countries.

From the implementation, five benefits were derived by the project practitioners across project phases. The benefits are including: improving the communication of safety between construction practitioners, safety personnel and owner; logistical details of construction safety tasks being fully addressed in the preconstruction phase; early identification and elimination of safety hazard as the project progress; derive awareness in safety culture toward construction workers; and easy to allocate resources and track safety performance. Despite, five inevitable challenges were identified including: limited use for integration of 4D building model; lack of expertise in modelling the safety features; poor design of systematic construction model to be integrated with safety planning; difficult to formulate the safety tools in 4D model; and difficult to apply safety control due to congested city environment (i.e., impact on neighbouring building's structural stability). Hence, the five fundamental components are inevitable in order to develop an initial framework of ASRC system for BIM-based construction projects.

4.2 Findings-Content Analysis Technique

A five-fundamental components of ASRC system were recognised. The fundamental components shall be taken as the indicators to develop framework grounded by Malaysian perception (i.e., architect, engineer, safety manager, and designer or modeller). Each component is discussed in turn for the development of BIM-based ASRC system in Malaysia construction industry.

1) Formation of 4D building model

Based on the result, it is indeed that the integration between building design and construction planning is important to form a 4D building model across project phases. This proclamation is supported by the statement from respondent 4 stating *"both element (i.e., building design and construction planning) are inevitable for the fact that they bring significance in the development of 4D models"*. This includes the detail drawing of the models, building components, construction sequences and construction activities. In addition, respondent 1 stating that *"these two elements are compulsory to develop 4D building model by integrating 3D model from Revit Software and construction schedule from CPM (Critical Path Method) or Naviswork"*. Certainly, Revit and Naviswork are the software used in Malaysia's BIM-based projects for the development of 4D building Model.

Table 2 Model of ASRC system from Finland, US, Thailand and China [2], [13], [14], [24]

Fundamental components/ theme	Country			
	Finland	**US**	**Thailand**	**China**
Formation of 4D Building Model (BIM)	• Consist of ***Building Design*** and Construction planning • Focus on work *breakdown structure* ***(WBS)***, geometry, temporary structures and supports.	• Consist of ***Building Design*** and Construction planning. • Focus on ***WBS,*** *schedule and cost,* temporary structure and supports, equipment and machineries	• Consist of ***Building Design*** (i.e., Building components, dimension, & space) and Construction planning (i.e., construction sequencing and *activities or* ***WBS***).	• Consist ***of Building Design*** (i.e., Building components,& detail drawing) and construction planning (i.e., construction activities, ***sequencing, and scheduling)***
Safety Aspect	• Combining the ***safety rule-based algorithm*** *with* ***rule checking process*** (i.e., rule of interpretation, model preparation, execution, checking reporting, and safety correction) by perceiving on ***hazard identification*** and ***safety parameter*** (safety rules & regulation from OSHA).	• Combining ***safety parameter*** (i.e., safety rules and regulation, safety guidelines, and best practices from OSHA and industry) with ***safety rule checking process*** (i.e., rule of interpretation, model preparation, execution, checking reporting, and safety correction) for every hazard to develop the ***safety rule-based algorithm***.	• Develop the ***safety Rule based Algorithm*** by distinguishes and combining three (3) safety elements including:(1) ***hazard identification*** (i.e., working at height); (2) safety measure planning (i.e., safety activities & requirement); and (3) safety control task (i.e., safety accomplishment evaluation).	• Real time safety status is developed by distinguishes three (3) safety elements including: (1) ***hazard identification*** (i.e., project structural elements and neighbour affected components); (2) safety control strategies; and (3) risk analysis in construction sequences.
ASRC Components	<u>*5 components*</u> • Location of planned project (i.e., entrance/exit route) • Crane management plan • Fall protection plan (floor & wall) • 4D visualisation of slab formwork(falling prevention) • Visualisation of wall demolition procedures	<u>*4 components*</u> • Crane management plan • Excavation risk management • Fall protection plan (floor, wall and roof) • Location of planned project (i.e., entrance/exit route)	<u>*2 components*</u> • Fall protection plan (floor &wall) • Fall offset perimeter for column and beam construction	<u>*3 components*</u> • Safety visualisation of diaphragm wall • Visualisation of earth-retaining wall • Visualisation of vicinity components (i.e., underground pipelines, and neighbouring buildings)
Benefits	• Improved communication of safety. • Eliminate hazard as the project progress	• Improved communication among the construction personnel. • Details of construction safety tasks being fully addressed in the pre-	• Eliminate hazard as the project progress • Improves communication • Derive awareness in safety culture	• Effective virtual tool to identify hazard. • Easy to allocate resources and track safety performance.

Fundamental components/ theme	Country			
	Finland	US	Thailand	China
		construction phase.		
Challenges/ Barriers	• Limited use for integration of 4D building model. • Lack of expertise in modelling the safety features	• Poor design of systematic construction model to be integrated with safety planning • Lack of expertise in modelling the safety features	• Poor design of systematic construction model to be integrated with safety planning • Difficult to formulate the safety tools in 4D model	• Difficult to apply for safety control due to congested city environment (i.e., impact on neighbouring building's structural stability).

2) Safety aspect

Unanimously, hundred percent (100%) of the respondents agreed that four (4) safety elements which comprises of rule based algorithm, rule checking process, hazard identification and safety parameter shall be fused together to develop a comprehensive safety aspect. As been highlighted by respondent 3 "to develop the algorithm, hazards (i.e., falls, hit by object, electrocution, stuck in/between the object & fire) and safety parameter (i.e., Occupational Safety & Health Act 1994, and Factory &Machineries Act 1967) shall be perceived". This statement is similar to the concept of model from Finland. Moreover, this assertion is corroborates with the idea of respondent 1 which suggesting "the model from Finland shall be used to develop a complete database of ASRC System". This indicates the safety aspect from Finland's model is applicable to be implemented in Malaysia's BIM-based projects.

3) ASRC components

Foremost, seven (7) main components of ASRC system were identified which comprises of: 1) location of planned project (i.e., entrance and exit route); 2) crane management plan; 3) excavation risk management plan; 4) safety visualisation of diaphragm wall; 5) visualisation of earth-retaining wall; 6) visualisation of vicinity components; and 7) fall protection plan (i.e., for floor, wall and roof). In other instances, fifty percent (50%) of the respondents (i.e., respondent 1 and 2) suggesting that 4D visualisation of slab formwork with needed falling prevention is vital to be implemented. However, as for the safety manager perception (respondent 3), this component is not necessary to be applied. The probable reason is because this safety component does not comply with the rules and standards in Malaysia. Besides, it could be costly to realize this feature. This implies that 4D visualisation of slab formwork with needed falling prevention is unnecessary for ASRC system in Malaysia

4) Expected benefits

Heretofore, 100% of the respondents are expecting five (5) benefits could be derived from the implementation of ASRC system including: 1) improve communication of safety between construction practitioners, safety personnel and owner; 2) show the details of construction safety tasks during the pre-construction phase; 3) identify and eliminate hazard as the project progress; 4) derive awareness in safety culture across project phases; and 5) easy to allocate resources and track safety performance.

5) Anticipated challenges

In particular, four (4) challenges were anticipated by all four (4) respondents including: 1) limited use for integration of 4D building model; 2) lack of expertise in modelling the safety features; 3) poor design of systematic construction model to be integrated with safety planning; and 4) difficult to formulate the safety tools in 4D model. Despite the fact that ASRC system is difficult to be applied due to congested city environment (as stated by respondent 1), respondent 2 and 3 otherwise denied by stating that this challenge could be avoided by various means (i.e., discern on the neighbour building's structure before construction begin). This indicates that it is not a major problem to be faced by the practitioners.

Given the above, based on the amalgamated ASRC system models (from Finland, US, Thailand, and China) and results from the interview, a proposed initial framework of ASRC system for BIM-based projects in Malaysia shall be established.

5.0 A PROPOSED INITIAL FRAMEWORK FOR BIM-BASED ASRC SYSTEM IN MALAYSIA

5.2 Initial Framework for BIM-Based ASRC System

Figure 2 illustrates the initial framework of ASRC system for BIM-based projects in Malaysia. This initial framework shall be used for the purpose to develop a comprehensive ASRC system for BIM-based projects. The framework is comprised with 5 significant phases (i.e., 4D BIM formation, safety aspect, ASRC components, expected benefits and challenges, and the final outcome from the implementation).

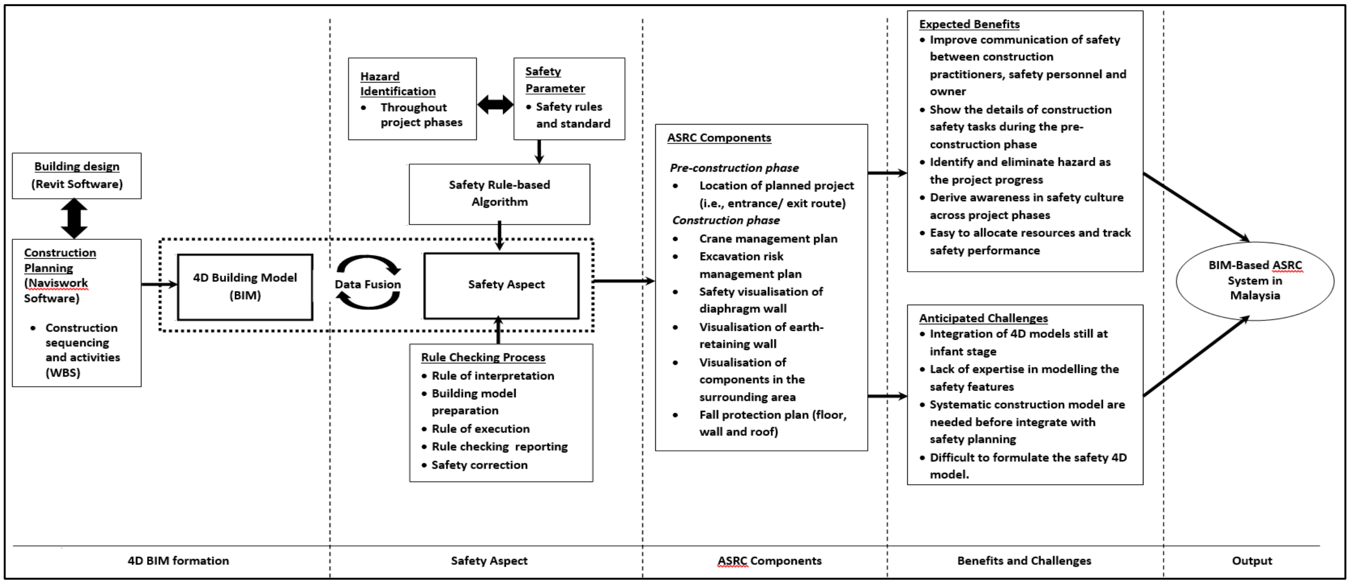


Figure 2 A proposed initial framework of ASRC system for BIM-based projects in Malaysia

6.0 CONCLUSION

At present, ASRC system is yet to be developed in Malaysia BIM-based projects [16]. Hence, this research distinguish four (4) models of ASRC system from Finland, US, Thailand and China. Five fundamental components from the models have been observed which includes: 1) formation of 4D building model (BIM); 2) safety aspect, 3) ASRC components; 4) expected benefits derived from the system; and 5) anticipated challenges in adopting the system. These components are vital in the development of BIM-based ASRC system throughout project phases. In spite, the components were used as the indicator to propose an initial framework of ASRC system in Malaysia BIM-based projects. The framework was discussed based on various perceptions (i.e., architect, engineer, safety manager, and designer or modeller). As a consequence, it has been confirmed that the initial framework of ASRC system is important in the future development of safety in BIM-based projects. A further research is to document various components of safety rule checking algorithm and to establish the visualisation structure of ASRC system across project phases. The results will be reported in the next conference.

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