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An evaluation of the interfacial bond strength of kenaf fibrous concrete and plain concrete composite

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ABSTRACT

The deterioration of concrete structures is a matter of critical concern as it threatens the durability and strength of concrete structures. Kenaf fibrous concrete composite (KFCC) can be used with advantage in new structures such as precast elements, as well as the strengthening, repair and rehabilitation of old structures to improve their durability properties. These structures are composite components, with parts as Plain concrete (PC) and others as KFCC. This study, therefore, investigated the interfacial bonding behaviour between KFCC and PC. Shear, tensile and compressive tests were carried out to measure the bond strength in shear, direct tension and compression respectively for PC to PC, PC to KFCC and KFCC to KFCC interface. Three different types of concrete grade (25, 35, and 45 MPa) were produced for the KFCC and one type of concrete grade (35 MPa) for the substrate PC. The outcome of the test showed that KFCC had an excellent interlock with the surface of the PC substrate, and thus, gives bond strength greater than the strength of PC. New concrete with the highest concrete grade of 45 MPa ensued in high compressive, tensile and shear bond strength.

1. Introduction

Concrete infrastructures in most countries around the world are facing a rapid loss of serviceability, safety and suffering damages from increasing and unpredictable live loads which they are exposed and subjected to in service (Shin and Wan, 2010; Banthia *et al.*, 2014). These civil infrastructures such as roads, sewers, and the built infrastructure of commercial, domestic and public buildings are the basis of any community's health, safety and prosperity. Consequently, they must be kept in good and functional state at all time (Banthia *et al.*, 2014). In response to infrastructure damaged, new construction materials that are sustainable, reliable, effective and economical such as bio composites are used in constructing overlay and patching the damaged or deteriorating part of the structures (Tayeh *et al.*, 2013a; Denarié and Brühwiler, 2006). Bio composites or green materials are the next solutions for sustainability approach in building material and structures nowadays (Drzal *et al.*, 2001). The usage of bio composites in engineering application is meant to achieve the target of creating a green building. Bio composites contain natural fibres which offer lots of advantages such as renewability, recyclability, biodegradability, low specific gravity and provide high specific strength (Izran *et al.*, 2014; Yatim *et al.*, 2011). Using bio composites in the construction industry will also help to reduce the manufacturing of petroleum-based material which helps in reducing cost efficiently. Combination of two different concretes is common in the building structures. Bonding of two concretes plays an essential role in the effectiveness of the structural system. Different strength of concrete, different ages of concretes and type of the concretes affect the bonding strength mechanism at the interface.

There are some parameters also included that influence the interfacial bonding behaviour such as moisture condition, amount of reinforcement crossing the interface, the compression resistance of weaker concrete, the roughness of the interface mode, the presence of cracking or the stress caused by the normal forces that are acting across the interface (Casal, 1960). Application of biocomposites in enhancing the bonding of concretes will gradually help to increase the efficiency of the building system. The mechanism behaviour of the combination of concretes plays an important role in the structural system. Many applications involved in the bonding of concretes such as repairing, casting joints or precast element connection requires large amounts of cement in them for them to develop an adequate bond with the substrate.

In the context of sustainability, an equally grave concern is that cement production is an environmentally damaging process that generates five percent of global CO_2 emissions (Banthia *et al.*, 2014). Nevertheless, the global production for cement is still increasing, and it was estimated at 4.3 billion tonnes in 2014, translating into a 6.7% increase compared to 4Bt produced in 2013 (The European Cement Association, 2014). Consequentially, the global construction industry is under pressure to dramatically reduce its CO_2 emissions (Banthia *et al.*, 2014). Using Kenaf fibres in the concrete has been proved to overcome the problem since Kenaf can absorb three times CO_2 compare to other plants (Lam and Jamaludin, 2015; Ogunbode *et al.*, 2015). The use of KFCC as replacement of existing conventional concrete to be used for repairing and rehabilitation purpose may give a great impact in engineering application towards sustainability. Recently, many entities have used use bio fibres in the reinforcement of Portland cement concrete (PCC) structures to increase the tensile strength, flexural strength, tensile ductility, flexural toughness, reducing the drying shrinkage, density of concrete and infusing the concrete with self-strain sensing capability of the concrete composite

(Ogunbode *et al.*, 2016; Lam and Jamaludin, 2015; Ramaswamy *et al.*, 1983; Hasan *et al.*, 2012; Ali *et al.*, 2012; Nadgouda, 2014; Vajje and Krishna, 2013; Filho and Joseph, 1999).

Research outcome has shown biofibrous concrete composites (BFCC) to possess the potentials that make it suitable for repair, retrofitting, rehabilitation of reinforced concrete structures (RCS) and as new construction material (Banthia *et al.*, 2014). Such attributes associated with BFCC as described by Parveen et al. (Parveen *et al.*, 2012) is its lightweight, improved durability, ductility, sustainability and relatively low cost of production. The improved durability and low density of BFCC related with its flexural and tensile properties make the main idea to use it in rehabilitating and strengthening the regions where the structure is exposed to high mechanical loading and severe environmental stress worthwhile. All other parts of the structures remain in normal structural concrete as these parts are subjected to relatively reasonable exposure. Usually, there always exists a weak connexion between the bond strength of the old and new concrete structures during strengthening and rehabilitation of concrete structures and rehabilitated, or repair of concrete structures is deemed successful when the good bond is achieved between the old and the new concrete (Momayez *et al.*, 2005; Gorst and Clark, 2003; Mu *et al.*, 2002). To successfully practice rehabilitation of deteriorating structures, the understanding of the mechanical properties behaviours at the interface between the old and the new construction materials is expedient (Tayeh *et al.*, 2013a; Tayeh *et al.*, 2013b; Ueda and Dai, 2005). The adhesion between the composite materials is a function of some factors, such as surface roughness and surface polarity of the composite components. In measuring the surface energies and bond strength of the composite material, an understanding of the interfacial adhesion between the fibre and the matrix has to be determined.

The fibre used in this research is a bio-fibre from Kenaf plant. Kenaf plants are blessing to mankind. Its high carbon dioxide (CO_2) assimilation rate and ability to clean the air by consuming large quantities of CO_2 and also absorb nitrogen and phosphorous from the soil, which is the main cause of the greenhouse effect has made Kenaf significant from the standpoint of environmental friendliness. Today Kenaf fibres are envisioned as an alternative medium to replacing conventional materials or synthetic fibres as reinforcement in composites. The low cost, no health risk, low density, high strength and modulus, and availability of Kenaf fibres in some countries have made it befitting for use in composites production (Ogunbode *et al.*, 2015; Patnaik, 2008). Due to the hydrophilic properties of Kenaf fibres, the fibre was subjected to surface treatment by sodium hydroxide reagents (NaOH) to improve the bond characteristics of the interfacial zone between the fibres and the cement matrix and also to reduce it hydrophilic properties (Mahjoub *et al.*, 2014). This reduction in the fibre water soption characteristics thus improves the fibre durability and reduces its bio degradability. The new concrete in this experiment is the repair concrete, which is the KFCC concrete.

This paper presents results from an experimental test program carried out to fully understand the benefits and potential of KFCC as repair material in concrete structures. This study helped to understand the morphology and strength of the interface bond strength developed between old concrete and the KFCC repair material. Shear test and tensile test were used in quantifying the bond strength in shear and direct tension, respectively.

2. Experimental programme

2.1 PC and KFCC properties

The mix design is in concomitant with the British DOE procedure. For this research, four different grade of concrete produced. For the NC substrate, a mean compressive strength of 35 N/mm^2 at 28 days was produced. The KFCC was designed to achieve three different grades at 25, 35, and 45 N/mm^2. The NC and KFCC contain Type I ordinary Portland cement with a specific gravity of 3.15. River sand with a maximum size of 5 mm, fineness modulus of 2.49, and 10 mm maximum size of crushed granite were used. The fibre used is 50 mm Kenaf fibres which have already undergone surface modification by mercerization treatment method. Figure 1 presents a curl and 50 mm chopped Kenaf fibre used in reinforcing the concrete. 0.75 % volume fraction of the Kenaf fibre was included in the KFCC mix. 1 % superplasticizer was used to improve the workability of the concrete mixture. The mix proportions based on the four different grade of concrete is illustrated in Table 1. The control specimens used consists of 100 x 100 mm cube for the compression strength test in determining the ultimate strength of the concrete grade, 100 x 100 x 300 mm prism for compression bond strength test, direct tensile bond strength test and shear bond strength test.

(a) Curled kenaf fibre (b) 50mm chopped kenaf fibre

Figure 1 *Kenaf fibre*

2.2 Specimen preparation

In conducting the test, PC specimen which serves as the substrate and KFCC specimen which serves as the repair or retrofitting material (new concrete) were produced. These two different materials were combined into a single composite specimen and tested. In producing the composite material, two days water cured PC samples were surface prepared to receive and bind to the fresh cast of KFCC samples. A deep groove roughness surface pattern of the substrate was made as shown in Figure 2. After the roughening of the surface, the PC substrate is further cured in water until 28 days from the date of casting.

Table 1 *Mix proportion based on the four different grade of concrete*

Type of concrete	Concrete Grade	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Course Aggregate (kg/m^3)	Water (kg/m^3)	w/c ratio	Kenaf fibre (kg/m^3)
Normal	35	460	230	761	969	0.5	-
KFCC	25	383	230	903	903	0.6	1200
KFCC	35	460	230	761	969	0.5	1200
KFCC	45	575	230	727	888	0.4	1200

Figure 2 illustrates the pattern of the roughened surfaces of the old PC specimens. These specimens represent the first and the old prism substrate of 28 days for the direct tensile and shear test. The PC substrate specimens were subsequently placed into the prepared wooden moulds. The KFCC mixture was then carried out using a pan mixer and successively cast on 15 minutes moistened and wiped dried old PC grooved roughened surface at 28 days of casting PC in the mould.

Figure 2 *Roughness surface pattern of old PC specimens*

2.3 Compression test

Compression testing using the modified standard practice for capping concrete based on ASTM C1552 (2015) was carried out. The test provided a plane surface on two bearing surface of samples which purposed to provide a consistent and standardised procedure for compression testing. Capping plate was used having a thickness of not less than 25 mm. The size of each unit is 100 x 100 x 300 mm. Three layers of concrete units were attached to form multi-layered composite concrete sample as shown in Figure 3 and 4. Increasing compressing load was applied to the sample until ultimate failure thus, the maximum compressive load of was obtained at the interfacial bonding. The cracking behaviour was observed. The concrete grade of PC units used was 35 MPa and for KFCC units were 25, 35 and 45 MPa. The result from this test was plotted in the graph of compressive bond strength versus the type of concrete with different grade and presented in Table 2 and Figure 5. The interface failure mode of the compression test sample for KFCC and PC are presented in Figure 6. The PC sample should a catastrophical failure pattern compared to the KFCC sample that had a ductile failure pattern due to the presence of the kenaf fibre in the concrete.

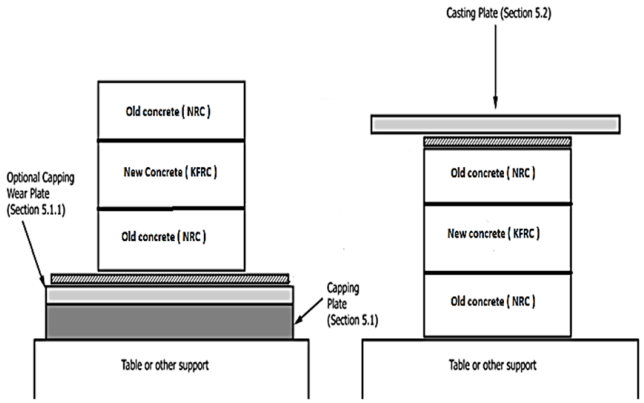

Figure 3 *Schematic procedure for compression test (ASTM C1522, 2015)*

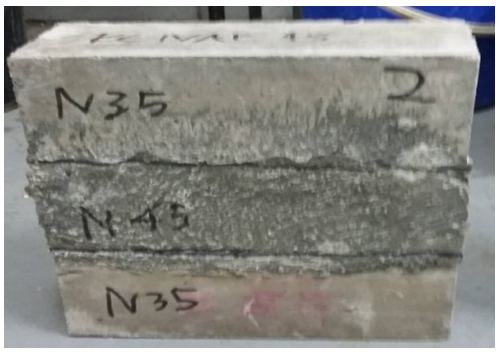

Figure 4 *Composite sample composed of KFCC unit bonded to PC substrate unit for compression test*

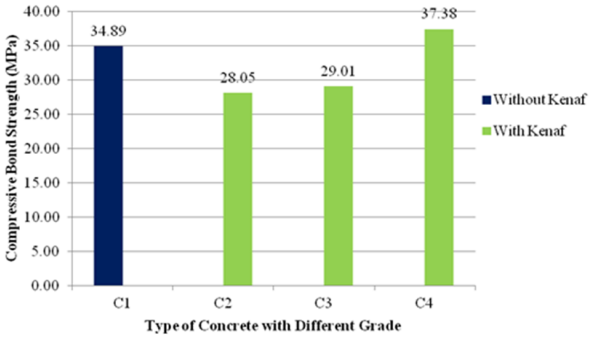

Figure 5 *Average compressive bond strength values (T_{av}) for each type of concrete at different grade of concrete*

Figure 6 *Interface failure mode of compression test sample (a) KFCC (b) PC*

Table 2 *Compressive strength obtained from each sample*

Sample ID	Concrete Grade (MPa)		Max. Force (P) (kN)	Compressive Stress (C) (MPa)	Average C_{av} (MPa)	SD
	PC Old concrete substrate	PC/KFCC New concrete				
C1	35 PC	35 PC	1020.60	34.02	34.89	1.76
			1107.30	36.91		
			1012.20	33.74		
C2		25 KFCC	893.10	29.77	28.05	1.49
			817.80	27.26		
			813.60	27.12		
C3		35 KFCC	859.20	28.64	29.01	0.89
			851.40	28.38		
			900.60	30.02		
C4		45 KFCC	1140.60	38.02	37.38	0.56
			1114.80	37.16		
			1109.10	36.97		

2.4 *Direct tensile test*

Direct tensile strength test was carried out using the modified standard test method for the tensile strength of concrete surface and the bond strength in accordance to ASTM C1583 (2013) specification. The bond strength and bond behaviour between the PC substrate and three different grades of KFCC material was investigated. In this test, the specimens used have a dimension of 100 x 100 x 300 mm as shown in Figure 7. Figure 7 (a) presents the Schematic procedure for direct tensile test ASTM C1583 (2013) while Figure 7 (b) illustrates sample of KFCC unit bonded to PC substrate unit for direct tensile test. The direct tensile strength test results were presented in Table 3 and Figure 8. The interface modes of failure are also illustrated in Figure 9.

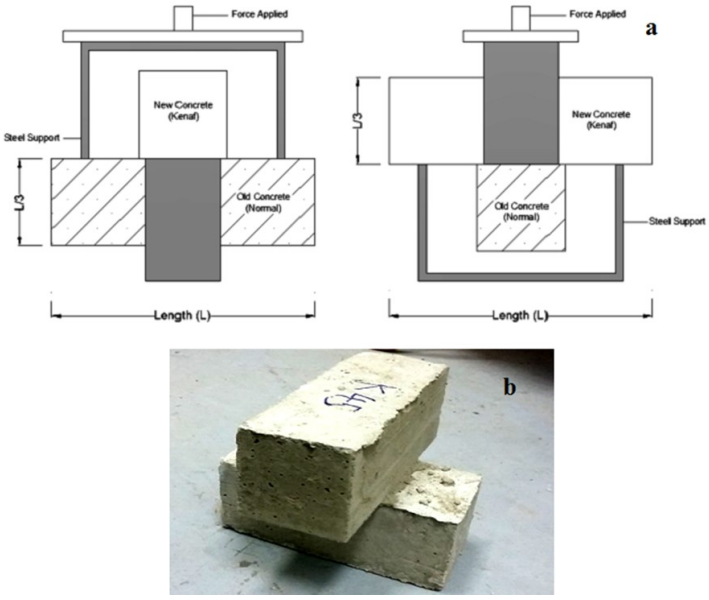

Figure 7 *(a) Schematic procedure for direct tensile test (ASTM C1583, 2013) (b) Composite sample composed of KFCC unit bonded to PC Substrate unit for direct tensile test*

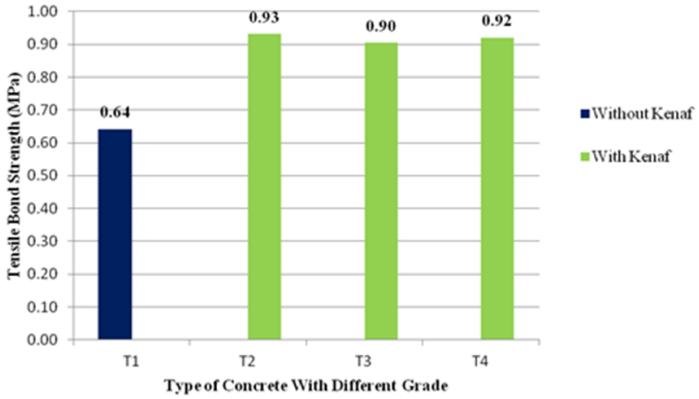

Figure 8 *Average direct tensile bond strength values (T_{av}) for each type of concrete at different grade of concrete*

2.5 *Shear test*

The Shear test was done to determine the shear bond strength of the concrete specimen at the interface using a modified simple beam with centre point loading in accordance with ASTM C293 (2016) specification. The shear bond strength and shear bond behaviour between the PC substrate and three different grades of KFCC repair material was investigated. In this test, the specimens used have a

Figure 9 *Interface failure mode of tensile test sample (a) KFCC (b) PC*

Table 3 *Tensile bond strength obtained from each sample*

Sample ID	Concrete Grade (MPa)		Max. Force (P) (kN)	Shear Stress (S) (MPa)	Average (T_{av}) (MPa)	SD
	PC Old concrete substrate	PC/KFCC New concrete				
T1	35 PC	35 PC	6.51	0.65	0.64	0.07
			5.67	0.57		
			7.07	0.71		
T2	35 PC	25 KFCC	10.15	1.02	0.93	0.10
			8.17	0.82		
			9.64	0.96		
T3	35 PC	35 KFCC	9.46	0.95	0.90	0.08
			9.45	0.95		
			8.21	0.82		
T4	35 PC	45 KFCC	9.97	1.00	0.92	0.10
			8.09	0.81		
			9.56	0.96		

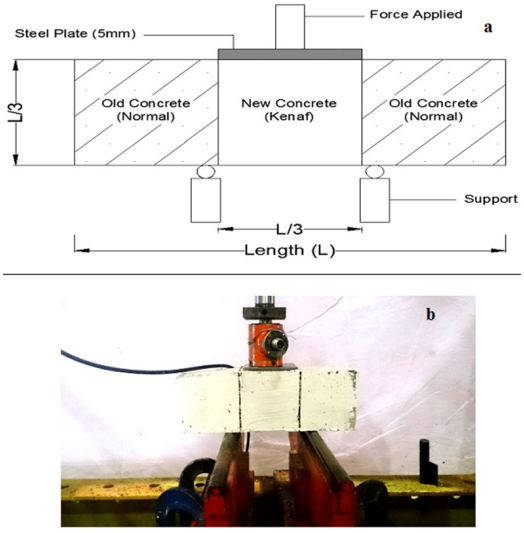

Figure 10 *(a) Schematic procedure for shear Test (ASTM C1583/C1583M) (b) Set up of composite sample composed of KFCC unit bonded to plain concrete substrate unit for shear test*

dimension of 100 x 100 x 300 mm. Figure 10 (a) presents the Schematic procedure for shear strength test based on ASTM C1583 (2013). While, Figure 10 (b) illustrates sample set up of KFCC for the shear test. The experimental shear strength test results are presented in Table 4 and Figure 11. The failure mode for the shear specimens is illustrated in Figure 12.

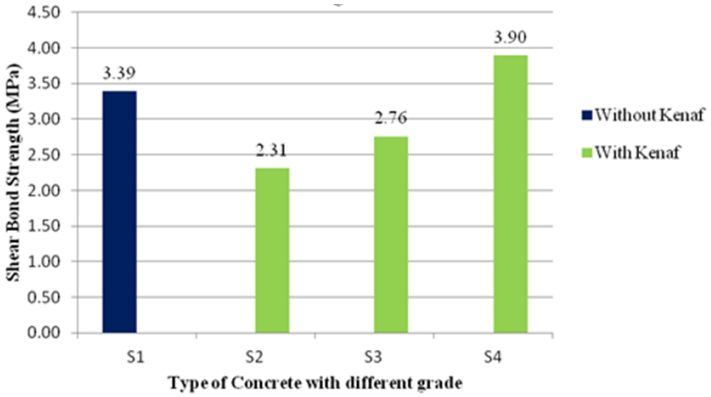

Figure 11 *Average Shear Bond strength values (S_{av}) for each type of concrete at different grade of concrete*

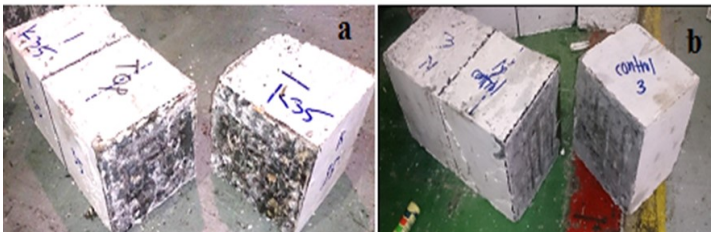

Figure 12 *Interface failure mode of shear test sample (a) KFC (b) PC*

Table 4 *Shear Bond Strength Obtained From Each Sample*

Sample ID	Concrete Grade (MPa)		Max. Force (P) (kN)	Shear Stress (S) (MPa)	Average (S_{av}) (MPa)	SD
	PC Old concrete substrate	PC/ KFC New concrete				
S1	35 PC	35 PC	38.4	3.84	3.39	0.07
			25.9	2..59		
			37.4	3.74		
S2	35 PC	25 KFBC	27.2	2.72	2.31	0.78
			14.1	1.41		
			28.1	2.81		
S3	35 PC	35 KFBC	26.1	2.61	2.76	0.38
			31.9	3.19		
			24.8	2.48		
S4	35 PC	45 KFBC	40.1	4.01	3.90	0.40
			34.5	3.45		
			42.3	4.23		

3. Discussion of results

Based on the result obtained from the cube test, the data showed that the PC has higher compressive strength compared to Kenaf fibrous concrete. Kenaf reduced the compressive strength of concrete since it is weak in resisting compression load. However, the target strength of Kenaf fibrous concrete can be achieved by increasing the concrete grade of PC. Besides, Kenaf fibrous concrete showed small crack compared to PC. This proved that the Kenaf fibrous concrete has more ductile failure mode compare to PC as shown in Figure 4. The compressive bond strength of PC with PC gave higher compressive bond strength compared with PC attached KFCC of the same grade. Kenaf reduced the compressive bond strength since Kenaf is weak in resisting compression load. However, by increasing the grade of KFCC, the compressive bond strength consequently increased. This outcome is in agreement with a similar study conducted by Shin and Wan (Shin and Wan, 2010) where the old concrete was combined with the different water-cement ratio which is tantamount to the grade of concrete. When using KFCC, the concrete grade was increased higher than PC to improve the compressive bond strength. Not only that, a sample with KFCC shows smaller crack compared to sample with PC only. Hence, KFCC helps concrete to maintain its integrity under load compared to the fibreless concrete.

The shear bond strength of PC with PC was relatively high compared to PC to KFCC with the same grade. However, by increasing the grade of KFCC, the shear bond strength thus increased, agreeing with the findings of Kang et al., (Kang *et al.*, 2015) that states that higher concrete grade gives higher shear strength. However, based on Shin and Wan (Shin and Wan, 2010) study, higher concrete grade of new concrete resulted in lower shear bonding strength. Besides that, from the experiment, for the sample with KFCC, it was found that the surface roughness pattern is not seen as the kenaf fibre filled some of the empty areas of the interlocking surface pattern as shown in Figure 5.5. Present kenaf fibre reduced the friction resistance of both surfaces and reduced shear bond strength between kenaf fibrous concrete and normal concrete. By inspection, it was found that KFCC sample surface roughness pattern as being filled with the fibre to aid the interlocking interface as can be observed in Figure 10a.

Kenaf has been proven to possess good tensile strength properties in concrete. KFCC exhibited tensile strength higher than PC up to 45%. By inspection, it was found that KFCC sample surface roughness pattern as being filled with the fibre to aid the interlocking interface as can be observed in Figure 7a. This showed that the kenaf fibre acts as the bonding element between two concrete surfaces to resist tensile force. By applying KFCC to any old PC for repairing purposes, it will contribute in term of tensile resistance better than normal concrete. Increasing the grade of concrete did not affect the tensile strength increase. However, it improved the compressive bond strength and shear bond strength at the interface. Hence, it could be noticed that KFCC is a good material for repair and retrofitting regarding mechanical properties.

4. Conclusion

Based on the results, observations and analysis of bonding behaviour of KFCC to PC interface; the following can be drawn:

i. The compressive bond strength of KFCC to PC is lower than that of PC to PC with the same grade. KFCC reduces the compressive bond strength of PC. However, the compressive bond strength of KFCC to PC can be increased by increasing grade of KFCC.

ii. Shear bond strength of the interfacial bonding of KFCC and PC is lower than that of PC to PC with the same grade. KFCC have a lesser shear bond strength compared to PC. However, the shear bond strength of KFCC to PC can be increased by increasing the grade of KFCC.

iii. Tensile bond strength of KFCC to PC is higher than that of PC PC with the same grade. KFCC improves the tensile bond strength with PC. However, the different grade of KFCC does not affect the tensile bond strength of KFCC and PC.

iv. Regarding cracking behaviour, the samples were cracked at the

bonding interface except for compressive test where the samples were cracked at the whole portion of the sample.

v. KFCC is a good material for repair and rehabilitation of damaged or deteriorating structure. KFCC can improve the tensile strength bonding to other concrete as well as compressive bond strength and shear bond strength by increasing the grade of KFCC. The use of KFCC for repairing and rehabilitation purpose can give a great impact on engineering industry towards sustainability.

vi. The application of natural fibres such as Kenaf fibre in concrete can exhibit economical and technical benefit for the construction industry. The green concrete developed has an environmental benefit which are of immense importance in the present context of the sustainability of natural resources.

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Evaluating students readiness, expectancy, acceptance and effectiveness of augmented reality based construction technology education

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ABSTRACT

Augmented reality (AR) has the potential to enhance the teaching and learning experience in construction technology which involves the learning of construction processes and understanding the construction elements. Augmented reality also provides the ability to change and improve the nature of education. This is due to the possibility of overlaying media onto the real world for content consumption using smartphones and tablets devices, which enables students to access information anywhere and anytime. However, before implementing a new approach to teaching, the state of whether the students are ready to use AR have to be identified. This also goes toward what the students expect when using AR in learning, how do they accept using AR and effectiveness of using AR in learning. Therefore, the purpose of this study is to (1) Identify the readiness of students on using AR in teaching; (2) Identifying what do the students expect when using AR in learning construction technology; (3) Identifying the student's acceptance of AR in learning; (4) The effectiveness of AR in construction technology learning. A quantitative method of analysis has been implemented measuring the mean score of objective 1-3 based on the student's responses to the questionnaire. On the other hand, the second phase of the study which is to determine whether using AR is effective in learning was done by comparing pre-test and post-test results. Results from the study show assuring indicators that students accept the usage of AR in construction technology education, the application also fulfils their expectations on what AR could aid in the learning process and for student's acceptance, the result shows that students accepted the usage of AR as a learning tool. Meanwhile, the results regarding AR effectiveness on construction technology displayed noticeable improvements regarding student's pre-test and post-test results with 68% of students display improvements in their scores.

1. Introduction

Mobile devices have been essential for people with the purpose of connecting and procuring information on the go. With the development and innovation made toward information and communication technologies, primarily toward mobile devices (mobile phone, tablets, etc.), the utilisation of technology in education has quickly been a norm in the last decade (Emiroğlu & Kurt, 2018). The utilisation of technology toward teaching and learning is best when combining the traditional elements of the classroom setting with the technological benefits of the technology (D'Souza et al, 2013, cited by Shirazi & Behzadan, 2014). However, Shirazi & Behzadan (2014) claims that students were still educated with the outdated method of teaching even with the advancements of technology currently present.

Therefore, with the adaptation of technology in teaching and learning, especially mobile devices, students can benefit from the availability of information and educational resources from their fingertips (Cadavieco, Goulão, & Costales, 2012; Herrington & Herrington, 2007; Ligi and Dr B. William Dharma Raja, 2017; McConatha, Praul, & Lynch, 2008).

This study aims to design, implement and assess the readiness, expectancy and acceptance of students toward a new technology-based pedagogical methodology based on augmented reality (AR) technology to support the prospect of a more engaging learning experience in construction technology courses for quantity surveying and construction degree programmes at Universiti Teknologi Malaysia.

2. Augmented reality in quantity surveying education

Augmented reality (AR) or mixed reality is defined as overlaying artificial or virtual effects onto the real world using computer-generated graphics or 3D models (Delello, 2014; Ismail, Bandi, & Maaz, 2018). Researcher Milgram et al. (1995) has explained that AR is a mixed reality that adds graphic elements to the real world as shown in figure 1.

Augmented reality is different to virtual reality which creates a virtual environment for the users. AR can aid users to better grasp the knowledge and functionality that had been delivered through the content with the help of computer-generated visualisation (Emiroğlu & Kurt, 2018).

With the current technological advancements, AR technology has come to the point that anyone can access it anywhere. This is due to

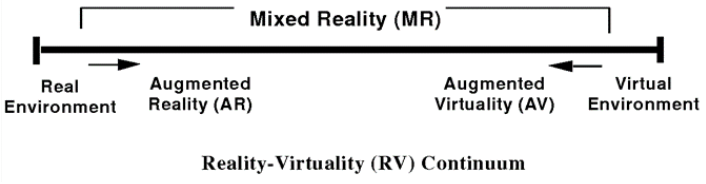

Figure 1 *Augmented reality: A class of displays on the reality-virtuality continuum (Milgram et al., 1995)*

the existence of smartphones. Nowadays, smartphones are so advance that it is considered as a minicomputer that fits on the palm (Anshari et. al, 2017).

Furthermore, smartphones are also considered the best tools to adopt AR technologies because of its onboard global positioning system (GPS) sensors, internet access, display panel and a camera. Hence, AR will be integrated into an application so that it can be accessed through a smartphone (Bower et. al, 2014; Mekni & Lemieux, 2014; Shirazi & Behzadan, 2014).

AR has been utilised in the various field from education, training, entertainment and simulations. The use of AR in education has gained momentum from the Z generation as it is easily accessible by mobile devices which is available to most Z generation students. AR's ability in visualisation helps to enhance student's creativity and understanding of the course (Hughes et. al, 2005; Pan et. al, 2006). Besides, many researchers concluded that AR's interactive simulations are more effective for cognitive learning (Dünser et. al., 2012; Georgilakis, Orfanos, & Hatziargyriou, 2014; Lee, 2012) Due to the rising popularity of mobile learning in the last decade, AR application for education has drastically increased in numbers and is mainly used with mobile devices (Emiroğlu & Kurt, 2018).

Quantity surveyors play an important part in the construction industry. Generally, quantity surveyor is a professional who is involved in a team comprising the client, architect, engineers, and contractors which combined the skills in drafting and interpretation of contract documents and to safeguard the ongoing progress of a construction project (Nnadi & Alintah, 2016; Shafie et al. 2014). Quantity surveyors serve as one of the team advisors toward the construction project. In the construction industry, the main source of information exchange is largely made through construction drawings, which until this day is in the form of 2D drawings. However, there are challenges in integrating or understanding 2D drawings into a 3D object which involves understanding the vertical and horizontal elements of the drawings (Suk et.al, 2017).

Therefore, construction technology courses are important for students, as the course teaches students how to understand and visualise what are the construction process involved on site. However, the attempt is insufficient as construction technology courses often utilise the outdated method of teaching and learning, same as other quantity surveying courses (Hasan & Rashid, K., 2005; Lee, 2009; Shirazi & Behzadan, 2014, 2015; Zakaria, Munaaim, & Khan, 2006). With the implementation of AR in construction technology courses, students can better understand, visualise and integrate the 2D drawings.

Research conducted regarding AR integration into the construction field are infrequent. In a research by Shanbari, Blinn, & Issa, (2016) on teaching masonry and roof components for construction management students using AR based videos, the students have positively agreed that AR had aided them in visualising roof construction and its components. Shirazi & Behzadan, (2015) has integrated AR into the teaching of building design and assembly project on construction students and reported that AR content increased the performance of construction management students in term of understanding the concept of the subject.

3. Student's readiness, expectancy and acceptance

3.1 Student's readiness

Advances in mobile technology have open doors to numerous method of learning in informal learning by incorporating flexible and ubiquitous access to information. Nowadays, mobile learning plays a significant role as a supplement to aid in formal education (Cheon et. al, 2012). The mobile devices can also access applications that can be used as aids in learning. With the usage of mobile devices in education being a regular occurrence, it is wise to incorporate AR technology into mobile applications as current mobile devices have technologies that could benefit AR with its variety of sensors and camera that is already built in into smartphones (Sommerauer & Müller, 2014).

However, before implementing a new method or technology in learning, readiness is a critical factor in determining whether a technology would be successfully implemented or not. Although there is a plethora of online resources and information regarding construction technology, student's should have the propensity to embrace and use the technology as part of their learning process (Mahat et. al, 2012). Therefore, the readiness level for this study will be referring to the student's readiness in using this application which will focus on the student's preference and applicability in using AR with a mobile phone in the teaching and learning process.

3.2 Student's expectancy

Expectation is defined as the act or state of looking forward or anticipating. (Chen, 2011) in his study has explored regarding student's technological expectancy toward e-learning system which used the expectancy-value theory in order to predicate that a student's behavioural intention is due to their technological expectancy and educational compatibility.

Chen added that for learning expectancy, most students expect to gain a higher level of knowledge when applying the new method. Chen has identified four general technological expectancies which are performance expectancy, effort expectancy, social influence and facilitating conditions as the dominant construct toward technological expectancy. Performance expectancy refers to an individual believes that using the technology would improve performance.

On the other hand, effort expectancy is whether a product is easy to use (Moore & Benbasat, 1991). Therefore for student's expectancy, this study will focus on the four general technological expectancies in the questionnaire that will be distributed during the data collection

3.3 Student's acceptance

Acceptance is often related to the intention and behaviours of the potential users of the technology (Davis, 1989). The technology acceptance model (TAM) commonly used to perceive the ease of use and the usefulness of a technology that could influence people's behaviour toward accepting the technology. However, the original TAM has been superseded by TAM2 which added the perceived usefulness and usage in terms of social influences and cognitive instrumental processes (output quality, relevance, demonstrability and ease of use). Moreover, TAM2 can predict the direct influence of subjective norms on behavioural intentions. Then TAM2 was improved by introducing facilitating conditions that directly relates to the actual behaviour of adopters, not to the behavioural intentions.

This new integration of TAM is called UTAUT which stands for a Unified Theory of Acceptance and Use of Technology. The addition is because people are generally motivated to use new technology if they are introduced to a particular technology, their intent to use new technology is usually not by themselves (Venkatesh & Davis, 2000). However, in 2008, Venkatesh, V., & Bala had proposed an extension on TAM, TAM2 and UTAUT which combines the model of the determinants of perceived ease of use . The determinants are computer self-efficacy, perception of external control, computer anxiety, computer playfulness, perceived enjoyment and objective usability into it.

TAM3 also consists of 17 constructs including various mediating and moderating relationships includes individual differences, system characteristics, social influences and facilitating conditions. For this study, the acceptance will be referring to the rate of student's acceptance to use AR technology in learning and continue using AR as part of their learning process. Therefore, in order to measure the rate of acceptance among students regarding AR technology, the use of TAM3 by Venkatesh, V., & Bala, (2008) will be used as the basis for the questionnaire.

4. Methodology

4.1 Research design

This study is held to address the 4 objectives of this study which is (1) Identify the readiness of students on using AR in teaching; (2) Identifying what do the students expect when using AR in learning construction technology; (3) Identifying the student's acceptance of AR in learning; (4) The effectiveness of AR in construction technology learning. This study will be conducting two types of test as a data collection method. The first and second phase of the study was conducted according to Table 1 below. The first phase is the questionnaires, which is intended to measure the student's readiness, expectancy and acceptance. However, the first three sections were conducted before the demonstration of the AR application to the students and the fourth and fifth sections were conducted when the students have been presented the AR application. The second phase of this study is conducted by implementing the pre-test, post-test method (Dimitrov & Rumrill Jr, 2003).

Table 1 *First and Second Phase Outline*

Phase	Descriptions	Execution
1st Phase	Section 1 (Basic Information)	Before AR Presentation
	Section 2 (Student's Readiness)	Before AR Presentation
	Section 3 (Student's Expectancy)	Before AR Presentation
	Section 4 (Student's Acceptance)	After AR Presentation
	Section 5 (Opinion & Recommendation)	After AR Presentation
2nd Phase	Pre-Test	Before AR Presentation
	Post-Test	After AR Presentation

4.2 Sample

41 first year Quantity Surveying undergraduates who enrolled in Construction Technology at Universiti Teknologi Malaysia, Skudai participated in the study. Construction Technology is the first course that exposes students to the construction design and methods in various building components such as substructures, super-structures and finishes with a low rise building.

The course learning objectives are 1) Understand the principle of design and method of construction of the related building components. 2) Describe the process of carrying out the work. 3) Sketch the plan, section, elevation and diagrams if necessary of all related building components. 4) Understand and describe the relevant construction materials. The students participated in this survey had no construction industry experience beforehand.

4.3 Instrument

For the first phase of the study, the instrument used for obtaining the data is by a questionnaire distributed to the students. The first section (basic information) of the questionnaire form is done to collect the data and identify the student's demographic. The questions solely ask the students regarding their age, gender, academic year and basic knowledge regarding AR and mobile learning.

The second section of the questionnaire is a closed format question which consists of 12 questions intended to measure the student's readiness toward mobile AR, the availability of mobile devices, access to the internet and the students' knowledge and experience in mobile AR. This format of questions has been used in the previous study (Abu-Al-Aish, Love, & Hunaiti, 2012; Lam et. al., 2011; Trifonova et. al., 2006; Yun & Murad, 2006).

The third section contains 12 statements of a five-point Likert scale (Boone & Boone, 2012) that is developed to evaluate the student's attitudes toward mobile AR. The Likert scale is used in similar studies regarding student's perception of the expectancy of mobile learning (Jacob & Issac, 2008; Kallaya, Prasong, & Kittima, 2009; Nassuora, 2012). The question has been modified to appear related to mobile AR. The scale ranged from 1- Strongly Disagree to 5- Strongly Agree.

The fourth section is focused on the student's attitude and acceptance and they will have to classify the practicality of mobile AR toward teaching and learning construction technology. The set of question will also be in the form of Likert scale where the scale ranged from 1- Strongly Disagree to 5- Strongly Agree. The approach of this study is adapted from Corbeil & Valdes-Corbeil, (2007) and Trifonova et al., (2006).

The second phase of this study will determine the effectiveness of mobile AR in education. The research design of a single group, pre-test and post-test was employed to determine whether AR images can help enhance the students understanding of construction technology. The students have been taught in class regarding pad foundations prior the test. However, they did not know that there will be a quiz at the demonstration. The students were asked to list out the components, materials and explain and sketch the construction process of a pad foundation. The students were given 15 minutes to answer the following questions:

1. List out the components of a pad foundation
2. List out the materials needed to construct a pad foundation
3. Explain and sketch in detail the process of constructing a pad foundation

Before the second test, students have presented the AR modules which include the 3D models, 3D animation video of the construction process and on-site scenario of constructing the foundations. The students were also given AR markers on foundations which can be accessed and overlaid as 3D models on the marker using their mobile phone. The marker was taken from the Building Construction Handbook by Chudley & Greeno (2006).

The list of foundations was 1) Isolated Pad, 2) Combined Pad. 3) Piling, 4) Raft Foundation, 5) Strip Foundation, 6) Cantilever Foundation. The 3D models were created using Sketch-up 2017 and imported to the AR application (ENTiTi) as an FBX file format and then can be viewed

from the ENTiTi application. The application can be obtained from Google Playstore and Apple Appstore. After the presentation of AR modules as shown in Figure 3, students were asked to re-take the quiz in 15 minutes and submit their answers when the 15 minutes is over.

Finally, the two test were graded and compared the mean scores of the pre-test and post-test. This comparison is made to analyse whether AR could enhance the students understanding and visualisation of construction technology.

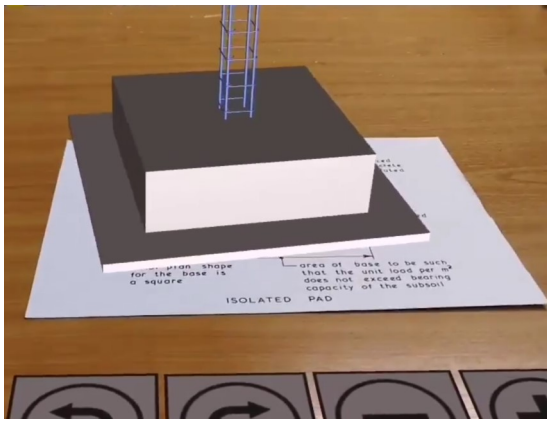

Figure 2 *Sample of the 3D model overlayed onto the marker*

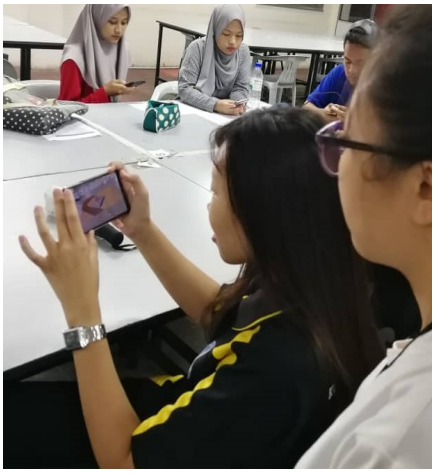

Figure 3 *Student's using AR application during demonstration*

4.4 Data analysis

The first phase of the study was done by using the quantitative data obtained and analysed using the Statistical Package for the Social Sciences (SPSS) software. Similar to this, the second phase of the study also done by inserting the data into the SPSS software.

5. Results

The results were separated into two phases, phase 1 is the questionnaire that has been distributed to the students and phase 2 is the pre-test and post-test which the students will have to answer the same questions before and after the presentation. From the analysis, it will highlight the student's readiness, expectancy, acceptance and effectiveness of the mobile AR application.

5.1 Student's readiness questions (SRQ)

Based on the data collected with the questionnaire, the student's readiness level is above average. This is shown in Table 2, the total mean score is 3.82 out of 5. Majority of the students are equipped and have the required tools to use mobile AR as shown in the results of SRQ1 until SRQ 10. Most students answered that they have smartphones that can connect to the internet and have a monthly internet subscription on their phones. This indicates that students are ready and the applicability of using mobile devices for learning purposes is present.

In contrast, the mean score of SRQ 11 and SRQ 12 which asked the students whether they have heard of AR is particularly low with the mean of 2.49 for SRQ 11 and 2.63 for SRQ 12. The mean score displays that the students may need guidance and instructions in order to use the AR application. Overall, the total mean for student's readiness is 3.82 which is good and shows that the students are ready to use mobile AR in learning.

Table 2 *Mean score of student's readiness*

Question	Mean	Std. Deviation
SRQ 1 - I have access to a smartphone	4.81	0.39
SRQ 2 - I have internet access on my smartphones	4.74	0.49
SRQ 3 - I usually surf the web using my smartphones	4.67	0.57
SRQ 4 - I depend on the university's Wi-Fi to access the internet	3.79	1.15
SRQ 5 - I have internet access when I'm outside the university	4.70	0.56
SRQ 6 - I subscribe to a personal internet plan on my smartphone	4.65	0.53
SRQ 7 - I have no problem with using the internet for learning purposes	4.30	0.94
SRQ 8 - I use smartphones as an aid to learning	4.51	0.63
SRQ 9 - My smartphone is very useful when I'm study-ing	4.40	0.66
SRQ 10 - Learning using smartphones in learning is in my interest	3.98	1.01
SRQ 11 - I have knowledge regarding AR	2.49	1.08
SRQ 12 - I have heard of learning using AR	2.63	1.02
Total Mean Score	3.82	

5.2 Student's expectancy questions (SEQ)

For the student's expectancy of using mobile AR, the questions focus on what do the students expect when using mobile AR after the briefing that had been done explaining AR and the potential of AR in learning. Based on the findings, it can be seen that the students are sceptical as shown by the total mean score of 3.71 out of 5.

Based on Table 3, the mean score of SEQ3 which ask the students "I am capable of using AR in learning" is the lowest with the mean score of only 3.21 out of 5. This shows that the students are doubting the benefits of mobile AR in education from the briefing. However, this is prior to the demonstration and activity that uses mobile AR in teaching and learning.

5.3 Student's acceptance questions (SAQ)

This set of questions addresses the behaviour of the students regarding accepting the usage of mobile AR. Based on table 4, the total mean score is 4.09, which makes it the highest score from all section of the questionnaire. This shows that the student already acknowledges and are attracted to mobile AR. The highest mean score from the set of question is SAQ 13 "group work will be more interesting when using AR" which means that AR will attract students in using the application for students as the medium to help them learn.

5.4 Effectiveness of mobile augmented reality

The graded scores from both pre-test and post-test were divided throughout both tests according to the student's name to identify the changes in the student's scores. The equation as shown as Equation 1 was used to identify the percentage of the number of students with

Table 3 *Mean score of student's expectancy*

Question	Mean	Std. Deviation
SEQ 1 - Learning using AR will be beneficial	3.67	0.68
SEQ 2 - I would like to learn construction technology using AR	4.02	0.64
SEQ 3 - I am capable of using AR in learning	3.21	0.94
SEQ 4 - Training is needed to understand how to use AR in learning	3.77	1.09
SEQ 5 - Learning using Mobile Augmented Reality will be interesting	3.79	0.83
SEQ 6 - I can understand better when learning using AR	3.60	0.73
SEQ 7 - Learning using AR will improve the interactive level between peers and lecturers	3.41	0.79
SEQ 8 - The curricular will be improved when using AR in Learning	3.53	0.86
SEQ 9 - I can visualise better when learning using AR	3.70	0.85
SEQ 10 - I can learn independently using AR	3.53	0.85
SEQ 11 - I can learn with my classmate using AR	3.86	0.71
SEQ 12 - The classroom activity will be more active with AR	3.88	0.85
SEQ 13 – I will be more excited to learn using AR	4.23	0.68
Total Mean Score	3.71	

Table 4 *Mean score of student's acceptance*

Question	Mean	Std. Deviation
SAQ 1 - I am eager to try new technology	4.19	0.76
SAQ 2 - The learning objectives of construction technology will be achieved better with AR	4.05	0.87
SAQ 3 - The usage of AR will improve productivity in learning construction technology	4.02	0.77
SAQ 4 - The usage of AR will improve the understanding of construction technology	3.98	0.80
SAQ 5 - Learning using AR is flexible in a learning session	4.02	0.89
SAQ 6 - Learning using AR is beneficial for the course	4.07	0.91
SAQ 7 - AR can help students visualise construction elements better	4.35	0.75
SAQ 8 - Students can understand sequential construction process better using AR	4.14	0.83
SAQ 9 - Learning using AR will help me visualise the process better	4.16	0.75
SAQ 10 - I am comfortable in using AR in learning construction technology	3.81	0.93
SAQ 11 - I will encourage my classmate to use AR to learn Construction Technology	3.91	0.89
SAQ 12 - Classroom activity will be more active	4.14	0.71
SAQ 13 – Group work will be more interesting when using AR	4.37	0.76
Total Mean Score	4.09	

increased scores, unchanged scores and decreased scores. From the graded test on table 5 below, it shows that sixty-eight percent of the students had an increase in scores with the aid of a 3D model in AR and some students could explain the construction process more thoroughly after using AR application in the second attempt. Twenty-nine percent of the students have their scores remains the same and unchanged. Only one student had a decrease in scores after using the AR application. The results show that there was significant evidence that student's understanding of construction technology was improved, as shown in the post-test.

Equation 1 Percentage calculation

$$p(\%) = \frac{n}{t}$$

p= percentage

n= number of students (Increase, unchanged, decrease)

t= total

Table 5 *Phase 2 Test Results*

Pre-test & Post-Test Results	Number of Students	Percentage (%)
Increase	30	68.29
Unchanged	12	29.27
Decrease	1	2.44

Table 6 *Phase 2 t-test Results*

	Post-test	Pre-Test
Mean	15.5610	12.9268
Observation	43	43
Correlation	0.677	
Hypothesised Mean Difference	0	
df	40	
t Stat	6.143	
P(T<=t) two-tailed	0.000 (2.9709E-7)	
Effect size (*d*)	0.155	

However, in order to find out whether the results are statistically significant, a t-test has been conducted to the test results. The paired samples *t-test* represent the student's performance comparison during the pre-test and post-test. As shown in table 6, the mean of the post-test is 15.56 and the pre-test is 12.93, this shows that the difference between the mean is 2.63. The results of the paired t-test on the two attempts show that the results that the students' performance after introduced to the concept of AR is significantly increased. The difference, although statistically significant, is small when using Cohen's (1988) guidelines.

6. Discussion

The first phase of the test shows that students are ready to use AR as a tool to aid in teaching and learning construction technology. Although some students had troubles in using the application at the beginning, the student's stated that they are more focused and active in the class session. Based on the questionnaire, the application demonstrated to the student's had are sceptical regarding the application. It can be seen by the total mean score shown in the student's expectancy. Although students were sceptical and have set average expectations on the application, the ubiquitous aspect of the application attracts students in learning and students actively participate in class when using AR as a learning tool. However, based on the expectancy questions, it can be seen that students expect that AR as a learning tool is troublesome. In contrast, the results for student's acceptance toward the AR application is high with the total mean score of 4.02 which is the highest among the three objectives. This shows that the students can accept the use of AR and teaching and are excited to learn when using AR.

Based on the results of the second phase, it shows that students could understand and visualise more with the help of 3D models projected by the AR application. Construction technology is defined as the study of method and equipment used to construct structures. Therefore, the understanding of construction technology could be considered achieved when the students could understand the construction process of a building element and each component and materials needed to construct a building. This confirms that AR images enhance the students understanding of the foundations and its construction process.

The results suggest that AR technology could enhance the understanding of construction technology courses for quantity surveying students. Although it is difficult to visualise the construction process and the structure of the foundation, the students can illustrate and visualise it using AR technology. Moreover, with the implementation of AR in the syllabus, students who do not have the extensive field experience can understand and interpret the

construction process and components of the construction elements. Even though site visits at construction sites could enhance the students understanding, it is hard to conduct site visits that are tailored to the course outline.

With the integration of AR application in the student's syllabus, students can access the 3D image overlaid on the marker easily with the AR application. Nevertheless, to apply AR in the student's entire syllabus, it requires a lot of resources as this type of AR requires 3D modelling and animation videos. Different contents need to be developed to aid the students according to the course outline to develop the continuity of applying AR to the whole syllabus. More research efforts have to be conducted to simplify the integration of AR and the content.

Understanding and visualising construction elements is important for quantity surveying students to better prepare them for the industry. Therefore, with the implementation of AR in the teaching and learning process of quantity surveying students, the construction technology course can be enhanced.

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Causes of building construction related accident in the south-western states of Nigeria

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ABSTRACT

Within the focus of the outcome of any construction activity is the realisation of minimal cost, timely delivery and quality-oriented structure. Nevertheless, above all is the safe execution of the construction site activities, which is a matter of life, most especially lives of the operatives. The study aimed at the identification of the common types of accident, the level of occurrence, as well as the causes of the identified accidents, in order to enable subsequent development of practicable preventive measures against such occurrence. Through an extensive literature review, eighteen (18) different types of accident were identified and were subsequently classified into seven (7) categories. Moreover, well-structured and self-administered questionnaires were administered to construction stakeholders (clients, consultants, contractors, health and safety experts, and the artisans), with the data analysed descriptively, using Relative Important Index via Likert scale. The outcome revealed the four categories of frequently occurring accidents to be: contact with working tools, vehicle-related, slip and trip, and falls. Some crucial inclusions in the list of causes are failure of edge protection, safety standard violations, overloading of scaffold and crane, wrong placement of ladder, loss of control over body movement, failure in the designs, absence of warning signs, over speeding of vehicle, wrong selection of working tools, non-usage of personal protective equipment, improperly installed equipment, horseplay, and poor housekeeping. The study shed light on the most frequent caused of accident which is instrumental to establish a safety planning and precautions.

1. Introduction

The input of the construction industry in the development of a nation cannot be overemphasized, being among the largest industries that significantly subscribe to nation's development (Babalola et al., 2015). The industry is found to have contributed 4.18% to the Nigerian economy (Tanko et al., 2017), as it produces commercial, educational, government, industrial, medical, military, religious and residential buildings. Nevertheless, activities ranging from site clearance, excavation, concreting, blocklaying to roofing are embarked upon on site, such activities which involve the use of a plethora of tools, equipment, and machinery which pose a great danger to the operatives on the building construction site (BCS). Besides, the nature of the construction site coupled with the high platform at which workers operate, and the weather conditions that these workers are exposed to serve as threats to their safety. However, such accidents are identified to include falls from heights/falling hazards (Orji et al., 2016), explosion (Hovden et al., 2008), vehicle-related accidents (Edwards and Nicholas, 2002), fire outbreak (HSE, 2006), electrocution/electrical incidents (Nkem et al., 2015), roof construction falls (Weeks, 2011), contact with electric current (Umeokafor et al., 2014), and fall of heavy objects during lifting. Consideration must be given to the fact that different types of accident happen at different construction sites, as types and causes of an accident have been identified by various scholars (Williams et al., 2018; Radmin, 2017; Asanka & Ranasinghe, 2015; Socias et al., 2014; Maloney, 2012; Jørgensen et al., 2010; Gambatese et al., 2008; Baksteen et al., 2007; Bellamy et al., 2007; Chi et al., 2004; Haslam et al., 2004). However, accident is considered as one of the obstructive agents of construction activities, as its occurrence interrupts site works, disables construction workers, reduces contractors' profit, destroys equipment, and extends project delivery period. The incidence is rightly described as an unplanned and unexpected occurrence (Hollnagel, 2004), which upsets a planned sequence of work; resulting to loss of production, injury to personnel, damage to plant and equipment and eventually interrupting production flow. The usual occurrence of all these safety threats (accidents) has made the industry tagged as an accident-prone sector (Hunter, 2011). Nevertheless, the reasons behind the occurrence of accidents on the BCS are not far-fetched, being simply because of the types of activity (Al-Tabtabai, 2012), as well as the dangerous operations (Asan & Akasah, 2015) that are performed on site. This motivated Idoro (2011) to conclude that the occurrence of construction site accidents is at a very high magnitude, while Tahir et al. (2008) described the construction sites as an industry having the potential of creating numerous hazards and dangers to workers with the capability of resulting in injuries or death. Moreover, Aniekwu (2007) and Udo et al. (2016) submitted that construction activities take place in the open and exposed to the weather. On a general note, many factors are

responsible for accidents ranging from chemical impairment, engagement of incompetent personnel, lack of awareness and enforcement of safety regulations, mechanical failure of construction machinery/equipment, non-vibrant professionalism, poor regard for safety by people involved in construction projects, physical and emotional stress. However, in many cases, poor safety culture (Misnan et al., 2008) is responsible for occupational accidents, while unsafe acts (Asan & Akasah, 2015; Ibrahim, 2012; Abdul Hamid et al., 2008) of employee's pool very high. In an attempt to holistically address the accident scenarios in Nigeria, an exploratory study was carried out to identify and establish the most frequent categories of accident and the proximal factors responsible for the identified ones. This became necessary following the fact that accident statistics are dear to come by in Nigeria (Orji et al., 2016, Agwu & Olele, 2014; Umeokafor et al., 2014; Ehi, 2010), and in identifying these types of accident it would permit the development of workable preventive measures against the occurrence of accident.

2. The Types and Causes of Building Construction Accidents (BCA)

An accident does not just happen, a factor is responsible, and the principles underlying the accident prevention techniques are the identification and control of these causes. Nevertheless, in order to position a workable preventive measure in the improvement of the overall safety performance, investigation into the root causes of the construction accidents is indispensable (Abdul Hamid et al., 2008), and with the corroboration of Khosravi et al. (2014) clear understanding of the factors playing key roles in accident causation serves as a precursor to its prevention. Besides, emphasis was laid by Hinze et al. (1998) on the fact that the first step in preventing an accident is the determination of the risk factors that are responsible for the accident, implicating that for any successful preventive measures to be implemented there is need for the determination of the root causes of the accident. It is, therefore, imperative to take the initial step of determining the causes of the identified categories of accident, which are discussed below.

2.1 Contact with Objects Accident

Electricity, welding arc flash, and working tools are usual objects that workers do always have contact with during the progress of construction activities. Electrical workers are the people that are commonly affected by electrical injuries or electrocution (Al-Tabtabai, 2002), which is consequent upon their exposures to cables or machines carrying electric current, working without personal protective equipment, contact with energised power line, improperly installed or damaged equipment, and safe voltage or earth failure. Where electric arc welders operate, arc flash is not an uncommon occurrence, as welding works require a high degree of experience, carefulness and supervision, being a hazardous activity. However, gases (in gas welding), electricity (electric welding), high temperatures, of which their combination or at separate instance affects workers' health significantly whenever they are in contact with any. Equally, with the daily use of different kinds of tool in the execution of construction works, users of these tools are susceptible to having contact with the working tools/equipment resulting in injuries of varying categories, for instance loss of limbs. This type of accident is found to be as a result of failure or non-usage of personal protective equipment (Orji et al., 2016; Carrillo-Castrillo, 2013), poor condition of equipment/tools (Haslam et al., 2005), wrong selection of tools for a particular activity (Olatunji et al., 2007), and non-adherence to safety guidelines (Kadiri et al., 2014).

2.2 Vehicle/Machine-related Accident

Machine-related activities on site employ the use of machine for faster and effective operations. Though they are indispensable, yet they are characterised by eventualities that result in accident on the site. However, crane accidents, struck by moving vehicles, struck by operating machines, and defective machines are all identified vehicle or machine-related accidents (Oladiran & Sotunbo, 2012; Arslan & Kaltakci, 2008). Among the list of such defective machines, which are susceptible to accident, are backhoes, boilers, bulldozers, forklift, scrapers, tractors, winches, and the like. Arslan & Kaltakci (2008) were of the opinion that overturning of a tower crane do happen on site causing damages to structures. Hence, the identified causes of crane accident are failure to test the stability after assembling of crane, extension of the crane boom beyond manufacturer's specifications, overloading beyond the crane's capacity, and unstable or uneven ground conditions. The factors responsible for the vehicle-related accidents include visual or audible contact failure, mechanical failure, driving ability of the operator, crowding workers into one area (congestion), driving on slopes that are too steep, and speedy movement especially around bends.

2.3 Slip & Trip Accident

Safe Work Australia (2012) identified slip and trip as construction accidents that end up in thousands of injuries every year, resulting in bruises, cuts, dislocations, fractures, musculoskeletal injuries. Besides, slip and trip (Orji et al., 2016; Udo et al., 2016) can result in fall, and have been identified as construction accidents. However, responsibility lies in the hands of the design professionals and building materials manufacturers on the type of floor finishes or materials specified or produced respectively. According to Lin et al. (1995), slips occur to a site worker by losing with the surface of the ground traction as a result of wearing inappropriate footwear or when walking on slippery floor surfaces. Slip interrupts the normal pattern of human locomotion and results to a fall, while it constantly happens as the heel of the victim strikes the walking surface with an attendant forward slide (Lin et al., 1995). The occurrence of trips holds when a worker unexpectedly catches his foot on a surface or object, and very often workers trip on low obstacles that are very difficult to notice, for example, loose mats or cables from electrical equipment, uneven edges in flooring, untidy tools, and opened drawers. The wet, greasy or highly polished surface is identified as an agent of slip and trip and coupled with this are poor housekeeping and horseplay by worker.

2.4 Fall-related Accident

Falls from holes in floor, ladder, roof, on the same level, scaffold, stair or ramp, and falling objects are the predominantly classified fall-related accidents on BCS. McDonald & Hrymak (2002) and Irumba (2014) opined that falls-from-height are the leading causes of injuries to operatives and deaths of workers on the construction sites, while HSE (2015) rated falls as three in ten injuries to workers (41 out of 142). Sejas (2014) and Orji et al. (2016) corroborated other scholars declaring that the leading cause of deaths is fall, and in addition to this was the research of Al-Tabtabai (2002) on Kuwait construction industry, where it was figured out that 30% of reported accident cases on site was as a result of falls from heights. However, working at height is indispensable by the workers (Freeman, 2015) as construction works involve structures of many storeys, necessitating the climbing of either unsteady scaffolding or unstable ladders in handling activities. Moreover, fall on the same level is classified as being a unique accident taking place on the construction site, having its severity lower than that of ladder, roof, and scaffold. Al-Tabtabai (2002), Tappin et al. (2004), Nolan (2011) and Mewes (2017) combined this type of fall with slip and trip, with the believe that slip and trip result in fall, and therefore treated alike, howbeit fall on same level is a unique accident on its own.

Table 1 *Summary of Types of Accident on Building Construction Sites*

Types of Accident	Authors													
	Radmin (2017)	Orji et al. (2016)	Asan & Akasah (2015)	Socias et al.(2014)	Maloney (2012)	Jørgensen et al. (2010)	Gambatese et al. (2008)	Baksteen et al. (2007)	Bellamy et al. (2007)	HSE (2006)	Chi et al. (2004)	Haslam et al. (2005)	Al-Tabtabai (2002)	Lin et al. (1995)
1.Contact with objects														
Contact with electricity	√	√	-	-	√	√	-	√	√	-	-	√	√	-
Contact with tools, welding arc flash	√	√	-	-	√	√	√	√	√	-	-	√	√	-
2.Vehicle/Machine Related														
Crane accident	-	-	√	-	√	-	-	√	√	-	-	-	√	-
Struck or run over by moving/ operating machine	√	√	√	-	√	√	√	√	√	-	-	√	√	-
Overturned vehicle	√	-	-	-	√	-	-	-	-	-	-	√	√	-
3. Slips and Trips	-	√	√	-	√	-	-	-	√	-	-	-	√	√
4. Fall Related Accident														
Fall from roof	√	√	√	-	√	√	√	√	√	√	√	√	√	-
Fall from scaffold	√	√	√	-	√	√	√	√	√	√	√	√	√	-
Fall from ladder	√	√	√	√	√	√	√	√	√	√	√	√	√	-
Fall from holes in flooring	√	√	-		√	√	√	√	√	√	√	√	-	-
Fall on the same level	√	√	√	-	√	√	-	√	√	√	√	√	√	√
Fall on stair or ramp	√	√	√	-	-	√	-	√	√	√	√	√	-	-
Falling or flying objects	√	-	√	-	√	√	-	√	√	√	-	√	√	-

Furthermore, the last of the fall-related accidents is the falling object, of which workers on site are prone to the danger of falling objects whenever they position themselves or carry out activities beneath where overhead work is being performed. Moreover, the analysis carried out by Al-Tabtabai (2002) on Kuwait construction sites, reported that 355 falling objects out of 1182 construction accidents were falling objects, thereby resulting in the second leading accident in Kuwait. Besides, as identified by Umeokafor et al. (2014), 13% of site accidents resulting in death in the Nigerian construction sites are as a result of fall of heavy objects, particularly during lifting. Further identification of falling object as one of the fall-related accidents on construction sites were made by Haslam et al. (2005), Chahuayo (2011), Gürcanli & Müngen (2013), Sattineni (2014), Goh et al. (2016), and Li et al. (2016). However, the causes of the fall from heights are unstable ladder, faulty or poorly constructed scaffold, inadequate training (Orji et al., 2016), engagement of defective equipment, improperly maintained or inadequate scaffolding (Aniekwu, 2007), failure/absence of edge protection, insufficient physical and mental capacities of roof worker, roof not designed to support exerted weight, non-usage of fall arrest system, scaffold not complying with safety standards, user's error, overloading of scaffold, wrong placement of ladder, loss of control over body movement, failure of the strength and stability of ladder, design failure of the stairs, and user's negligence in the use of hand rails. Additionally, the fall on same level traces its causes to uneven or damaged floor, loss of grip on surface/floor, and poor housekeeping, while that of falling objects are caused by absence of warning sign in danger zone, failure/non-usage of personal protective equipment, failure of object securing (attachment), and failure of hole cover due to substandard material or cover being overloaded. Table 1 shows the summary of the four categories of accident considered mostly occurring in the Nigerian BCS.

3. Research Methodology

3.1 Method

Having the main goal of this research in focus, a reasonable number of scholarly articles were reviewed to identify eighteen different types of accident. These were consequently categorised into seven groups following experts' input. Besides, an exploratory study was carried out to establish the most commonly occurring accidents on BCS in Southwest Nigeria. Thus, four categories of accident were established, being above the average mean of 2.99 after the statistical analysis, and these formed the focus of this research. Additionally, proximal causal factors responsible for the accident were included in the questionnaire, while the basis for the selection of the study questionnaire was the reviewed literature of safety-related articles.

3.2 Sampling Technique

The research adopted non-probability purposive sampling technique, patterned after the studies of Tanko et al. (2017) and Dodo (2014), as this method afforded the researchers in reaching the target groups, with a high output of response.

3.3 Population and samples

The target population included the construction stakeholders, while three hundred and ninety-three were reached with the open-ended questionnaires in the South-western states of Nigeria. However, the sampling frame spans across the clients (public and private organisations), consultants (Arch, QS, and Engineers in government ministries, academic institutions, medical institutions, contracting and consultancy firms), safety professionals (in contracting organisation, government ministries, consultancy firms), and craftsmen (masons, carpenters, electricians, plumbers, and welders employed in contracting organisations, government offices and self-employed).

3.4 Data Analysis

The questions on the types, frequencies, and causes of BCS accident were pilot-tested using some construction experts for the purpose of confirming the consistency and reliability of the questionnaires. However, in testing for the reliability and consistency of the instrument, Cronbach's alpha was used through the application of Statistical Package for the Social Sciences Software Version 20 (SPSS V20), thus providing a good reliability value of 0.977. Since

Cronbach's alpha provides a measure of internal reliability of items in a questionnaire, the value (0.977) establishes the fact that the research items are measuring the same thing. Moreover, the collected data were descriptively analysed using the Mean and Relative Importance Index (RII), in relation to Tanko et al., (2017), Fung Man-Kam (2014), Muhwezi *et al.* (2014). The RII provides the relative importance of the causal factors of each type of accident. Equally, the computation made use of the average formulas as the respondents indicated their opinions based on their experiences in the construction industry on a 5-point Likert scale. The mean and the RII were statistically calculated for each item with the usage of the following formulas:

i) Mean for the types of accident;

$$\ddot{X} = \frac{1n^1+2n^2+3n^3+4n^4+5n^5}{N}$$

Where, $\ddot{X}$ = Mean; n^1 = number of respondents for "Never happen"; n^2 = number of respondents for "Rarely happen"; n^3= number of respondents for "Neutral"; n^4= number of respondents for "Sometimes happen"; n^5 = number of respondents for "Always happen"; N = Total Number of respondents.

ii) RII for the causes of accident:

$$RII = \frac{\sum ni*pi}{N*Rv}$$

Where, ni = number of respondents choosing pi; pi = 1 to 5 on the scale of Likert; N = total number of respondents; Rv = highest value in Likert scale.

Furthermore, the perceptions of each group of respondents were weighted while the overall weights were averagely calculated. Besides, by employing RII statistical analysis, the factors which are above the overall average are considered to be the important factors responsible for the causes of accidents, as shown in Tables 7-10.

4. Results and Discussion

4.1 Demographic Information of the Respondents

The demographic information of the respondents is presented in Figures 1 and 4. In relation to the three hundred and ninety-three (393) questionnaires that were administered, three hundred and ten (310) were correctly answered and found useful for this research. The missing data were treated and replaced using the SPSS software. The usable questionnaires represent 78.88% of the administered questionnaires, which was adequate for the establishment of types, frequencies and causes of accidents. The years of experience of the respondents, as indicated in Figure 1, are less than 3years (21%), 3-5years (22%), 6-10years (17%) and above 10years (40%). However, with the level of the percentage of 57% (17+40=57) of the respondents having an experience above 6years, their responses are adequately enough to rely upon and found very useful for the analysis.

The academic qualifications show ND (15%), HND (30%), BSc/PGD (30%), MSc (15%), PhD (6%) and others (4%), with an indication that 81% of the respondents are holders of degrees. Taking cognizance of the possessed academic achievement, their experiences in the construction industry are not to be reckoned with as being "shallow" while their contributions are vital and significant. This is presented in Figure 2.

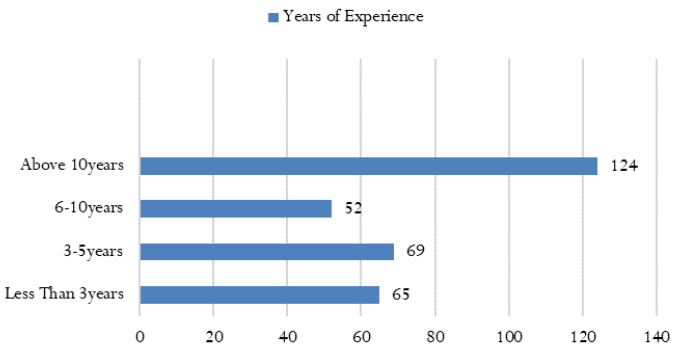

Figure 1 *Year of Experience*

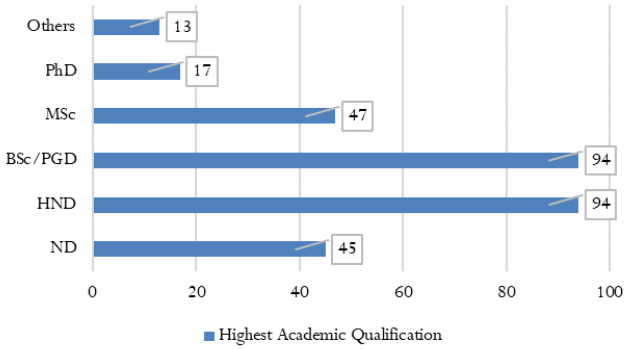

Figure 2 *Highest Academic Qualification*

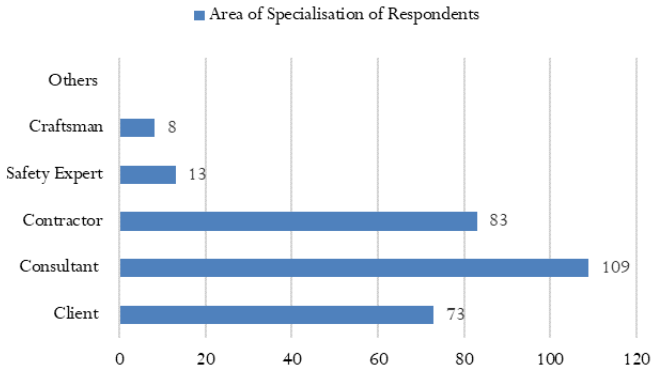

Figure 3 *Area of Specialization*

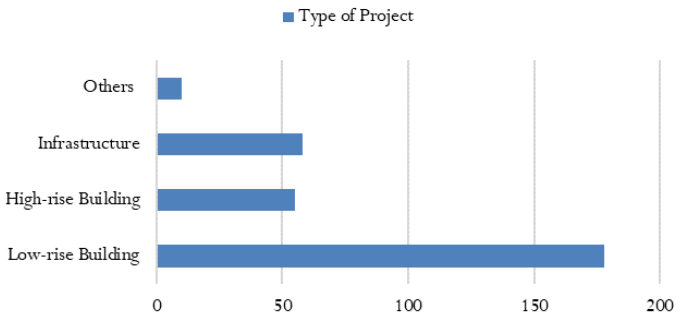

Figure 4 *Type of Project*

The areas of specialisation (professions) of the research respondents, as indicated in Figure 3, are client (23%), consultant (35%), contractor (27%), safety practitioner (4%), craftsman (3%), and others (6%). The consultants comprise of the architects, engineers, builders, and the quantity surveyors.

Table 2 *Summary of Responses on the Types and Frequencies of Accident on the BCS*

Categories of accident	Response (%)					N	MS	Results		
	NH	RH	N	SH	AH			Av. MS	SD	Rank
Contact with objects	9.7	21.3	14.5	35.8	18.7	310	3.33	2.99	1.267	1
Vehicle/machine related	13.95	23.5	12.6	36.1	13.9	310	3.13		1.302	2
Slip and trip	15.2	21.0	15.8	34.5	13.5	310	3.10		1.303	3
Fall-related	11.0	34.8	7.1	37.1	10.0	310	3.00		1.250	4
Lifting and handling	11.3	31.0	17.7	29.0	11.0	310	2.97		1.222	5
Collapses	23.9	25.2	10.6	27.7	12.6	310	2.80		1.398	6
Exposures to harmful substances	24.8	30.0	16.1	17.1	11.9	310	2.61		1.341	7

Table 3 *RII and Ranking of Causes of Fall-Related Accident*

Type of Accident	Causes	RII of Items	Rank	RII of Accident Type	Rank
Fall from roof	Failure of roof edge protection	0.623	23	0.640	7
	Insufficient physical and mental capacities of roof worker	0.674	20		
	Roof not designed to support exerted weight	0.632	21		
	Non usage of fall arrest system	0.629	22		
Fall from scaffold	Failure of scaffold edge protection	0.700	17	0.726	4
	Scaffold not complying with safety standards	0.745	6		
	User's error	0.722	13		
	Overloading of scaffold	0.738	10		
Fall from ladder	Wrong placement of ladder	0.745	5	0.747	1
	Loss of control over body movement	0.743	7		
	Failure of the strength and stability of ladder	0.753	3		
Fall from holes in floor	Hole cover failure due to substandard material	0.696	19	0.710	5
	Cover overloaded	0.699	18		
	Absence of edge protection or mark	0.736	11		
Fall on the same level	Loss of grip on surface /floor	0.707	16	0.708	6
	Loss of control over operative's own body	0.708	14		
	Uneven or damaged floor	0.708	15		
Fall from stairs	User's negligence in the use of hand rails	0.740	8	0.740	3
	Design failure of the stair	0.740	9		
Falling objects	Absence of warning sign in danger zone	0.761	1	0.743	2
	Poor housekeeping	0.727	12		
	Failure of Personal Protective Equipment	0.757	2		
	Object securing (attachment) failure	0.747	4		

In relation to Figure 4, 57.4% of the respondents are involved in the construction of low-rise buildings, 17.7% in high-rise buildings, 18.75% are into infrastructures, while 6.1% did not specifically indicate the scope of their operations. Hence, the involvement of the respondents makes it possible to know the types of construction accident and the rate of occurrence on the BCS.

4.2 Responses on the Types and Frequencies of Accident on the Building Construction Site

The distribution of the summary of responses on the categories and frequencies of accident on the BCS is shown in Table 2 below. Seven categories of accident are indicated in the table, while it can be deduced from the table that four categories of accident out of the seven categories are most prominent, being above the average mean of 2.99. The most frequently occurring accident is the contact with objects, having a mean score of 3.33, which ranks first. It is followed by the vehicle/machine-related accident (3.13), being the second in ranking, while the third is slip and trip accident (3.10). The fourth is the fall-related accident (3.00).

Tables 3 shows the causes associated with the fall-related accident. The causes of each subtype of accidents are clearly indicated in the mentioned table, together with the relative importance index and ranking of each factor causing the accident. However, as indicated in the table, twenty-three causes are responsible for the accident, thus covering the seven subtypes of accident. The RII as indicated in the table shows fall from roof (0.640), fall from scaffold (0.726), fall from ladder (0.747), fall from holes in floor (0.710), fall on the same level (0.708), fall from stairs (0.740), and falling objects (0.743).

In respect of the vehicle-related accident, twelve causes were identified across the three accident subtypes as shown in Table 4. The RII of each item as well as their ranking are all indicated. The RII of each subtype of accident with their raking are shown, having crane accident (RII=0.723), struck or run over by moving/operating machine (RII=0.701), and overturned vehicle (RII=0.736).

Table 4 *RII and Ranking of Causes of Vehicle/Machine-Related Accident*

Type of Accident	Causes	RII of Items	Rank	RII of Accident	Rank
Crane accident	Unstable or uneven ground conditions	0.681	11	0.723	2
	Failure to test the stability after assembling	0.731	6		
	Extending the crane boom beyond manufacturer's specifications	0.737	4		
	Overloading beyond the crane's capacity	0.743	3		
Struck or run over by moving/ operating machine	Visual or audible contact failure	0.684	10	0.701	3
	Mechanical failure	0.751	2		
	Driving ability of the operator	0.690	9		
	Crowding workers into one area	0.678	12		
Overturned vehicle	Driving on slopes that are too steep	0.704	8	0.736	1
	Moving over uneven ground	0.713	7		
	Being overloaded or unevenly loaded	0.736	5		
	Speedy movement, especially around bends	0.790	1		

Table 5 *RII and Ranking of Causes of Contacts with Objects Accident*

Type of Accident	Causes	RII of Items	Rank	RII of Accident	Rank
Contact with electricity	Contact with bared wires due to lack of Personal Protective Equipment	0.726	5	0.718	2
	Contact of worker or vehicle with energized power line	0.696	8		
	Improperly installed equipment	0.742	4		
	Safe voltage or earth failure	0.708	7		
Contact with equipment, tools	Failure of Personal Protective Equipment	0.719	6	0.761	1
	Poor condition of equipment/tools	0.774	3		
	Wrong selection of tools for a particular activity	0.775	1		
	Non-adherence to safety guidelines.	0.774	2		

In relation to Table 5, eight causes are in relation to contact with objects accident, which are responsible for the two subtypes. The table shows the RII of each item as well as their ranking. Equally, the RII of each subtype of accident with their raking are indicated, having contact with electricity (RII=0.718), and contact with equipment/tools (RII=0.761).

Table 6 shows the three causes associated with the slip and trip accident. Shown further in the table is the RII of each item as well as their ranking, having 0.738 as the overall RII.

In consideration of the relative importance index and ranking of the different types of accident, fall from ladder appears first (Av. RII=0.747) under fall-related accident in Table 3, followed by falling objects (Av. RII=0.743), while fall from stairs ranks 3rd (Av. RII=0.740). In vehicle/machine-related accident (Table 4), overturned vehicle ranks first (Av. RII=0.736), while crane accident follows as second (Av. RII=0.723), and the third in ranking being struck or run over by moving/operating machine (Av. RII=0.701). Besides, contact with objects type of accident (Table 5) has contact with equipment/ tools as first in ranking (Av. RII=0.761), while contact with electricity appears second (Av. RII=0.718). Moreover, slip and trip had no subtypes as earlier indicated in table 6, having RII of 0.738 as overall average. Significantly, giving regards to the overall ranking of all the types of accident, the order appears as contact with equipment/tools (RII=0.761), fall from ladder (RII=0.747), falling objects (RII=0.743), fall from stairs (RII=0.740), slip and trip (RII=0.738), overturned vehicle (RII=0.736), scaffold (RII=0.726), crane accident (RII=0.723), and the like. However, presented in Table 7 are the most important factors responsible for fall-related accident, as thirteen factors are indicated.

Table 8 contains the six most important factors responsible for vehicle-related accident, with the RII of each item and the ranking shown explicitly.

Table 9 shows the four most important factors responsible for contact with objects accident, with the RII of each item and the ranking shown clearly.

Table 6 *RII and Ranking of Causes of Slip and Trip Accident as Perceived by the Respondents*

Type of Accident	Causes	RII of Items	Rank	RII of Accident
Slip and Trip	Poor housekeeping	0.717	3	0.738
	Horseplay by worker	0.745	2	
	Loss of foot traction with the ground surface as a result of slippery, wet or highly polished floor surfaces	0.753	1	

Table 7 *Most Important Factors Responsible for Fall-Related Accident*

	CAUSES	RII	RANK
Fall-related accident	Absence of warning sign in danger zone	0.761	1
	Failure of PPE	0.757	2
	Failure of the strength and stability of ladder	0.753	3
	Object securing (attachment) failure	0.747	4
	Wrong placement of ladder	0.745	5
	Scaffold not complying with safety standards	0.745	5
	Loss of control over body movement	0.743	7
	User's negligence in the use of hand rails	0.740	8
	Design failure of the stair	0.740	8
	Overloading of scaffold	0.738	10
	Absence of edge protection or mark	0.736	11
	Poor housekeeping	0.727	12
	User's error	0.722	13

Table 8 *Most Important Causes of Vehicle/Machine-Related Accident*

	CAUSES	RII	RANK
Vehicle/machine-related accident	Speedy movement	0.790	1
	Mechanical failure	0.751	2
	Overloading beyond the crane's capacity	0.743	3
	Extending the crane boom	0.737	4
	Being overloaded or unevenly loaded	0.736	5
	Failure to test the stability after assembling	0.731	6

Table 9 *Most Important Causes of Contact with Objects Accident*

	CAUSES	RII	RANK
Contact with objects accident	Wrong selection of tools	0.775	1
	Non-adherence to safety guidelines.	0.774	2
	Poor condition of equipment/tools	0.774	2
	Improperly installed equipment	0.742	4

Table 10 *Most Important Causes of Slip and Trip Accident*

	CAUSES	RII	RANK
Slip and Trip accident	Loss of foot traction etc.	0.753	1
	Horseplay by worker	0.745	2

Table 10 contains the two most important factors responsible for slip and trip accident, with the RII of each item and the ranking unequivocally shown.

Accidents on site are described as agents of obstruction of activities, as the research identifies four categories of accident mostly occurring in the Nigerian BCS. These include contact with tools/equipment, vehicle/machine-related, slip and trip, and fall-related accidents. The causes of these accidents are explicitly indicated, both in the literature review and in Tables 3-6. The four categories are considered to be the most commonly occurring accident. Sequel to the perceptions of experts in construction industry the types, frequencies and the causes of accident are plausibly established. As indicated in Table 7, the thirteen most influential causes associated with accident involving falls are errors related to man, most especially the site operatives. By considering the non-provision of warning sign, it makes it possible for workers to experience falling objects accident on the BCS. The consciousness of the presence of warning signs or safety signals allows the workers to

either keep off the environment of such objects or exercise watchfulness when working within the vicinity of such objects. However, lack of precautions, that is, absence of warning sign (Rich, 2012; Oladiran et al., 2008) is sufficient enough in making workers fall victims of falling objects. The failure of workers in the usage of PPE (Chi et al., 2004) is another point of consideration in the building industry in respect to safety. Such PPE, which is inclusive of helmet and the like, reduces the impact of the striking or falling objects on the head of such victim. Though, the usage of PPE may not completely prevent the occurrence of accident but brings its impact to a lesser level if such accident takes place, particularly when objects fall on workers. In relation to the ladder accident, which is being caused by wrong placement, this corroborates the research of (Axelsson & Carter, 1995) that reported that low angle of inclination in the placement of ladder is a common contributing factor for ladder accident. The authors also reported that ladder accidents account for nearly 5% of all reported occupational accidents in the Swedish construction industry. In addition, another major cause of scaffold accident is the overloading of scaffold with working materials. Although some of these errors can be avoided where there is a close supervision. Besides, compliance with safety regulations by the workers is another way of avoiding such errors. In the same vein, for the ladder accident being caused as a result of ladder strength and stability, the onus is greatly on the supervisor to ensure that ladder of adequate strength is provided, tested and inspected before its usage. Nevertheless, to avoid this type of accident, inspection of the ladder is highly necessary, and such inspection should not be limited to ladder only but to other equipment and tools, as some of these equipment and tools are researched to be responsible for accident where they are deficiently provided (Goh et al., 2016), improperly maintained (Williams et al., 2018; Goh et al., 2016; Kemei et al., 2015), wrongly selected (Al-Tabtabai, 2002), and/or poorly installed. Besides, the contractor is under obligation to provide tools and equipment in compliance with the contract specifications, while the client should make adequate provision of fund available. Furthermore, in consideration of the falling of operatives on stairs, which is as a result of non-usage of hand rails, the type of instruction made available to operatives must be questioned. *Is there any specific instruction given to the workers vis-à-vis the usage of stairs? Is there any proper channel of communicating instructions to workers on the site? Is there any penalty for workers who flout safety regulations/instructions?* Plausible answers supplied to these questions will enable a good researcher to understand the root causes of such fall from stairs. In relation to failure of the design of the stairs, such design, which is the sole responsibility of the designers, may be ascribed to appointment of inexperienced designers, non-involvement of structural engineers in design stage, or poor workmanship of the contractor's workforce. Moreover, other causes that are of high importance under fall-related accident are traceable to poor supervision (Aniekwu, 2007; Safe Work Australia, 2002), lack of training (Goh et., 2016; Kemei et al., 2015; Kadiri et al., 2014), and lack of knowledge of workers (Azmi & Misnan, 2013; Al-Tabtabai, 2002), provided adequate research is carried out to explore the root causes. In furtherance to the above, the causal factors of machine-related, slip and trip, as well as contact with objects accident, have their root causes traceable to violation or disregards to safety regulations (Kemei et al., 2015), insufficient or deficient training (Kadiri et al., 2014), inspection challenge (Saurin, 2016), and/or lack of supervision (Aniekwu, 2007). Regards must, therefore, be given to the root causes of all these accidents to enable any preventive measures to be put up. For instance, failure to test the stability of crane after assembling (Schmidt & Clark, 2017)] can be adduced to lack of proper supervision (Aniekwu, 2007), lack of adequate instruction (Goh et al., 2016) or carelessness (Kadiri et al., 2016). However, all the causes of accident with high relative importance index are also indicated in Tables 8, 9, and 10.

5. Conclusion

The most frequently occurring accidents have been identified to be contact with tools/equipment, vehicle/machine-related, slip and trip, and fall-related accidents, while the factors responsible for each were explored statistically. Consideration of the appropriate preventive measures for occurrence of accident include: management enforcing compliance with safety standards and the use of personal protective equipment (safety belts, safety nets etc), correct placement of ladder through proper supervision, constant training on right selection and use of equipment/tools, correctness of design, inspection of equipment. Others include site discipline among workers, appropriateness in the usage of safety items, conspicuous location of warning signs, regular maintenance of tools and equipment, and reporting of accident. Additionally, with the confirmation of the high spate of accident occurrence in Nigeria BCS and the burning passion for its mitigation, a model of accident prevention will be developed, which is the next stage of the on-going research. The model will be cantered on the prevention of accident at dual-stage through the consideration of the involvement of various stakeholders including the clients, consultants, contractors, as well as the health and safety regulators.

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Automation of Concrete Usage Index (CUI) assessment using computational BIM

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ABSTRACT

Concrete Usage Index (CUI) is one of the very used sustainability criteria related to building materials available in the Malaysian and the Singaporean building standards. Often, CUI assessment is achieved either by manual calculation or semi-automated methods based on Material Take-off functionalities provided by the BIM tools. Both of these methods are relatively time-consuming, error-prone, and require much human intervention. The purpose of this paper is to develop a computational BIM-based tool for the automation of Concrete Usage Index (CUI) assessment and rating, called Auto-CUI. This tool takes advantage of the data embedded in the BIM model and the automated CUI compliance-checking which is developed using a Visual Programing Language (Dynamo for Revit). For validation purpose, this tool has been tested on a BIM model of an existing building and the results were compared with Revit Material Take-off method. Thus, Auto-CUI tool automates the process of data collection, calculation and the generation of the CUI report. In addition to that, the generated results are as accurate as the material take-off method. Auto-CUI will support design decision-making during the design stage by providing an interactive feedback of CUI actual score and rating. Thus, the project team will be able to compare different design options according to the concrete usage. Furthermore, it will allow designers to avoid CUI's cumbersome calculations and inaccurate outputs. Even though, the usage of this tool does not require programming skills, developing this tool further as a plug-in for Revit would be helpful in reducing computation time as well as enhancing the generation of CUI report.

1. Introduction

Building and construction sector has been heavily criticized for being a major contributor to the environmental degradation and global warming (Stadel et al., 2011). As a consequence, it is now believed that building professionals and stakeholders should act in order to alleviate these environmental impacts by adopting sustainable practices in building design (Dixon et al., 2012). The push forward to embrace sustainable practices in the building industry is supported by the establishment of several green building rating systems around the world. These green building rating systems consist of quantitative and qualitative metrics designed to evaluate building performance and guide the design and construction of green buildings (Wu, 2010). Building Research Establishment Environmental Assessment Method (BREEAM) is the first green building rating system which was founded in the U.K in the 1990s followed by several other rating systems such as Haute Environmental Quality (HQE) in France in 1996 and the Leadership in Energy and Environmental Design (LEED) in US in 2000 (Stephanie Vierra, 2014). Nowadays, numerous new green rating systems have been adopted in many other countries. For instance, Singapore has developed Green Mark in 2005, while GreenRE (GreenRE, 2015) and Green Building Index (GBI) (GBI, 2010) have been established in Malaysia in 2009 and 2013 respectively.

Design decision-making under the green rating system requirements is often very time-consuming due to the fact that collecting, managing and documenting relevant data is a very labour process (Wu, 2010; Wong and Kuan, 2014; Jalaei and Jrade, 2015; Ilhan and Yaman, 2016; Lim et al., 2016). For instance, materials selection in green buildings become depended on several new sustainability indicators and regulations, such as the material's embodied energy, carbon emissions, and Concrete Usage Index (CUI). It is not easy to predict the effects of material choices on the overall building sustainability, especially in the early stages of building design (Trusty, 2003). For example, one material choice could achieve a good thermal performance of the building indoor environment. However, the same choice may have a huge impact on the environment in term of concrete usage index. Therefore, building practitioners need more sophisticated methods and tools to assist them in material selection and grip the complexity of design decision-making under the criteria of sustainability.

Building Information Modelling (BIM) is a recently emerged digital concept and it is considered as one of the most promising developments in Architecture, Engineering, and Construction (AEC) industries. With the advent of BIM technology, the automation of building sustainability compliance checking according to the rating criteria becomes achievable (Wong and Kuan, 2014). Thanks to the BIM software that have opened their Application Programming Interface (API), hence, the user has access to their systems. Accordingly, many repetitive tasks in the BIM-based design process can be automated by developing rules and codes that are able to interact with the API of the BIM tool.

Concrete Usage Index (CUI) is one of the sustainability criteria related to building materials that have been adopted by Green Mark (Singapore) and GreenRE (Malaysia) rating systems. Currently, CUI assessment is achieved either by manual calculations or semi-automated methods based on Material Take-off functionalities provided by the BIM tools. Both of these methods are relatively time-consuming and require much human intervention. Thus, this paper aims to develop a computational BIM-based tool capable to assess the CUI of a building design and generate the CUI report automatically in a very short duration.

2. Literature review

2.1 BIM for Sustainable Materials Selection

In the past few years, many studies have argued that the application of BIM technologies for green building design has a great potential to support design -making (Wong and Kuan, 2014). By using BIM technologies and tools, building model is constructed digitally and loaded with different type of data that can support design decision-making and analysis through building lifecycle. Kriegel and Nies (2008) claimed that BIM can support sustainable design in various aspects which include building orientation optimization, daylighting analysis, energy modeling, and sustainable materials selection (Krygiel and Nies, 2008). Various BIM-based Frameworks, models, and tools have been developed as a part of integrating BIM technologies to support green building performance assessment and rating. For instance, (Kim and Jun, 2013; Lee et al., 2015; Lim et al., 2016) have developed Revit templates to support the assessment of different sustainability indicators such as the embodied energies of building materials and the Overall Thermal Transfer Value (OTTV). On the other hand, (Wong and Kuan, 2014; Ilhan and Yaman, 2016) proposed BIM-based tools for building sustainability assessment integrated to BREEAM and BEAM plus certifications respectively. Both these tools extract the required data from the BIM model and then, this data is processed through several rules and functions to reach the final score of specific sustainability indicators.

2.2 Computational BIM and Visual Programing Language (VPL)

Computational Building Information Modelling (BIM) is a design paradigm grounded on the use of algorithms and BIM-based rules for data extraction and management to meet design objectives and user needs. Often computational design is performed in building design using visual programming languages (VPL) tools such as Grasshopper and Dynamo to mention few. Taking Dynamo example, this tool allows the user to construct programmatic relationships using a Graphical User Interface (GUI) (Vandezande and Krygiel, 2015). Thus, rather than writing 'code' from scratch, the user is able to assemble custom relationships by connecting pre-packaged nodes together to make a custom algorithm. This can support project teams in manipulating the geometric and metadata embedded in the BIM model within Revit. Hence, automates repetitive tasks, and create efficient workflows to solve complex design problems. Kensek and Noble (2014) argued that capability of Dynamo in manipulating the parameters of Revit added an extra level of associativity and created new opportunities for cross-platform and cross-discipline collaboration (Kensek and Noble, 2014). Recently, new promising functionalities such as "Dynamo Player" have been included in Revit 2017.1 (Autodesk, 2017). Dynamo Player is designed to allow users without programming skills to execute Dynamo scripts with a click of a button.

Kensek (2015) claimed that Visual Programming Languages (VPL) can support sustainable building design analysis in the early stages of the design process (Kensek, 2015). Several studies (Asl et al., 2011; Kensek and Kahn, 2013; Kensek, 2015; Kim et al., 2015; Konis, Gamas and Kensek, 2016) implemented Visual Programming tools to create frameworks and workflows related to building performance analysis. For example, (Konis, Gamas and Kensek, 2016) developed a framework for building passive performance optimization for the early design stage. The framework implements a simulation-based parametric modeling workflow able to optimize several variables for building envelop configuration. In this workflow, Grasshopper has been used as the visual programming tool to manipulate design variables and run the optimization. Several other studies have implemented Visual Programming tool for building performance analysis such as Energy Efficiency and daylighting optimization (Asl et al., 2011), Overall Thermal Transfer Value (OTTV) assessment (Seghier et al., 2017), Structural analysis (Makris et al., 2013), Acoustical analysis (Andrea Vannini, 2015) and more. In this area, Edwin Guerra (2014) proposed a simplified problem-solving workflow for Dynamo which covers 3 key steps: identify the problem to explore, develop Dynamo script and explore (Edwin Guerra, 2014). Nevertheless, there is still no comprehensive VPL based model or workflow for building sustainability analysis. In addition, only a few of these studies integrate computational BIM concept into their workflows.

2.3 Concrete Usage Index (CUI)

The reduction of concrete quantities in buildings has many benefits that include cost-benefit, structure weight reduction and cleaner construction site. Building and Construction Authority of Singapore (BCA) has developed Concrete Usage Index (CUI) criteria, which aims at increasing the awareness regarding concrete usage in building projects. Several green rating tools have adopted CUI as a sustainability requirement in order to encourage the project team to use different materials and look for alternative design options. In both Green Mark and GreenRE rating tools, CUI weights up to 5 credit points. This number may seem to be insignificant compared to the total credit points of a rating tool. Nevertheless, CUI is considered as a prerequisite requirement for buildings seeking for gold or platinum certification. This means any project team targeting for these two certifications must achieve a CUI $\leq 0.50 m^3/m^2$ and $\leq 0.70\ m^3/m^2$ for gold and platinum certification respectively. In this context, achieving CUI requirement could be even more challenging.

Based on the CUI guide (Keung, 2012), the calculation of CUI consider only the superstructure elements which include structural and non-structural elements. It does not include the concrete used for external works and sub-structural works such as basements and foundations. As shown in Equation 1, CUI is defined as the volume of concrete in cubic meters to cast a square meter of constructed floor area.

$$CUI = \frac{Concrete\ Volume\ (m^3)}{Constructed\ Floor\ Area\ (m^2)}$$

Equation 1 *Concrete Usage Index (CUI) equation (Keung, 2012)*

3. Potential of Full Automation of CUI Assessment

Traditionally, CUI is computed by collecting the relevant data manually from 2D drawings, then, inputting this data into an excel template created for this purpose. This method could be very time consuming especially if the building in question is very large or has complicated forms. Chandra and Zhou (2014) argued that because the collection of data related to concrete quantities is very complicated, this method required design/engineering consultants to spend a week or more on the calculation process. The second method for CUI assessment is based on the use of Material Take-off functionality of the BIM tools such as

Revit. This method is able to extract the relevant quantities of concrete and the Constructed Floor Area (CFA) which are needed for the computation of Concrete Usage Index (CUI), hence it eases the complication of computing the CUI value manually. Nevertheless, this method is still not fully automated. Since most of the BIM software have opened their programming interfaces, tasks such as CUI can be automated by developing a tool able to extract the relevant data from the BIM model according to the CUI compliance (Chandra and Zhou, 2014). Often, BIM-based tools are developed using sophisticated languages such as C# and C++. However, this study explores and implements a visual programing language workflow using Dynamo for Revit for the development of the Auto-CUI assessment tool.

4. Methodology for automated CUI compliance checking

In order to streamline the compliance of CUI requirement and develop a computational BIM-based tool capable of assessing and rating the CUI automatically, a methodology that consists of three stages has been developed as shown in Figure 1. Wu (2010), Lim et al. (2016) and Kasim (2015) have adopted similar approaches in their studies related to the integration of BIM and green building certifications.

Firstly, the requirements of CUI were interpreted based on the sustainability-related regulations available in the relevant literature. In this step, the required parameters for CUI computation and the relationship between them are identified. Then, BIM-compatible rules for data extraction and management were created along with the preparation of the design environment of Revit to host the new parameters. Finally, Dynamo scripts for CUI assessment was developed to streamline the data extraction from the BIM model. The scripts are developed using a mix of Dynamo built-in nodes and several other nodes which are available in the custom packages of Dynamo library such as "Clockwork" and "Archi-lab". For validation purpose, the developed Auto-CUI tool was tested on a case study building and the results were compared with the conventional Material Take-off method.

It is worthy to mention, that there is various BIM software in the market capable to manage the information related to building materials in the BIM model. Though, in this study, Autodesk® Revit® is used as the BIM authoring tools and Dynamo as the Visual Programming tool. Both tools are linked together, hence, all the data in the BIM model can be extracted and managed by developing specific Dynamo scripts.

5. Findings

5.1 Limitations in the current method of CUI assessment

CUI assessment using Material Take-off can be considered as a semi-automated method. Although this method is more efficient compared to the manual calculation method, it still requires manual preparation of material quantities schedules of each building component separately. This preparation process includes the execution of filtering, grouping and sorting commands, then concrete quantities are summed up in each building element according to the floor level using an excel spreadsheet. Based on our observation, the Revit® Material Take-off tool has some limitations which are considered as an obstacle for the automation of CUI assessment. These limitations are as fellow:

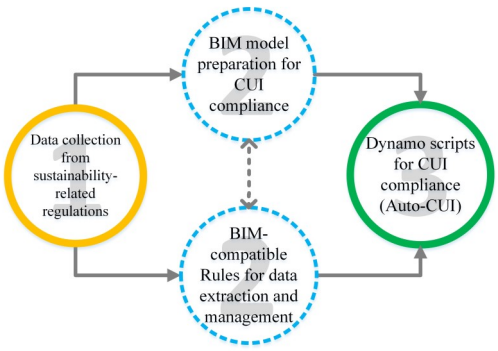

Figure 1 *Computational BIM-based workflow for the development of Auto-CUI tool*

Material Take-off schedules in Revit are created separately for each building element category. Although its consolidation does not take as long as the modeling process, it is still contributing to the time of the assessment process.

By using Material Take-off functionalities, the calculation results of different schedules cannot be combined between the different element categories. For example, in CUI case, the concrete volume in each elements category has to be summed manually from the relevant schedules to get the total concrete in the project.

The scheduling method is still not suitable for decision-making regarding CUI, because when the project team changes to a new design option, CUI calculation must be carried out again by going through the above tasks (limitations).

Thus, developing Dynamo scripts to overcome the above-stated limitations would increase the automation level and support project team in CUI assessment and rating.

5.2 Auto CUI tool development

5.2.1 CUI requirement interpretation

After reviewing the relevant literature related to the CUI requirement, a coding system that contains the most important quantitative and qualitative items has been developed as shown in Table 1. The outcome of this content analysis will consist the fundamental reference that will enable the development of the required rules for data extraction, which in turn will be used to develop Dynamo scripts for CUI automated-compliance checking. Yet, these required rules have to be developed by taking consideration of the limitation/capability of the BIM authoring tool Revit. Hence, the compliance of Revit and CUI is investigated in the next sub-heading.

5.2.2 Revit-CUI compliance

One of the critical issues to consider in the automation of CUI assessment is that the BIM model must be modeled correctly in order to extract data properly. According to the CUI guide (Keung, 2012), CUI report should contain the quantities of concrete in each level of the building. Technically speaking, this can create an issue related to the elements that span across multiple levels in the design such as columns and stairs. This issue can be solved if all building elements are modeled in each level (elements should not span to more than one level). Another issue that may create errors during data extraction is the naming of the assigned materials in building elements. For instance, a material as concrete should be spelled correctly in the material editor otherwise the volume of this material will not be taken into consideration in the calculation process and this may lead to erroneous results.

In order to provide the user a quick feedback of the building's design CUI value and the rating score during the design stage, three shared parameters have been added to the design environment of Revit namely; CUI (m^3/m^2), GreenRE/ Green Mark credit points and exclude from CUI calculation (see Figure 2). Shared parameters are the definition of parameters that can be added to families or projects. These

Table 1 *The interpretation of CUI requirement*

Coding system	Content	Comments/ Rules for CUI automation
Keywords	Concrete Volume, include only superstructure elements (structural and non-structural elements), exclude concrete used in external works and substructural	All concrete of the superstructure should be included in CUI calculation (using grouping and filtering functions)
Equation	$CUI = \frac{\text{Concrete Volume } (m^3)}{\text{Constructed Floor Area } (m^2)}$	Concrete has to be tracked in each building element, "Element Material" node from Clockwork package may be used for this purpose.
Requested data	Concrete quantities in building elements, total Constructed Floor Area (CFA)	Both of these data can be extracted from the BIM model.
Considered Building elements	Walls, Floors (Slabs), Roofs, structural Columns, beams, and stairs	Gather these elements using "All element of category" node, then filter the irrelevant elements.
Credit allocation logic	0.6 < CUI ≤0.7 0.5 < CUI ≤0.6 0.4 < CU I ≤0.5 0.35 < CUI ≤ 0.4 CUI ≤ 0.35	These logics will be used to automate the rating of building CUI within the BIM authoring tool (Revit).
Prerequisite requirements	GreenRE Gold ≥ 3 credits GreenRE Platinum ≥ 5 credits	A quick assessment of CUI can be useful in supporting decision-making regarding CUI.
Documentary Evidences	Calculation showing the quantity of concrete used for each floor level.	Two Dynamo script has to be created one for quick CUI assessment (to support Decision-Making) and the second for CUI report generation.

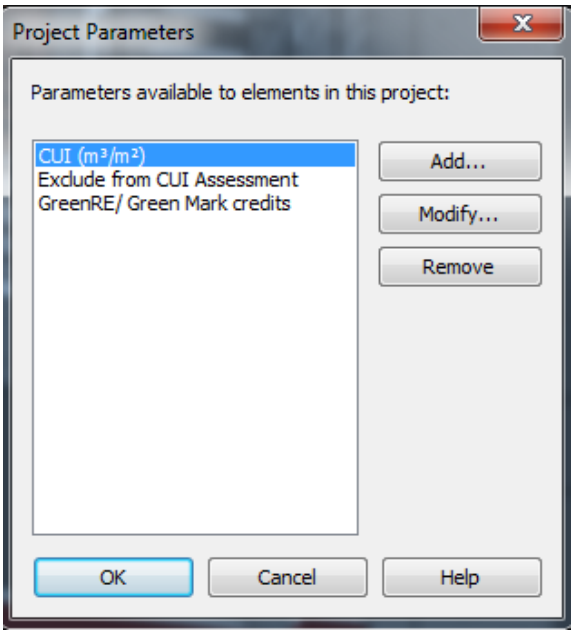

Figure 2 *New shared parameter for CUI assessment workflow*

parameters are stored in a text file independent of any family file of Revit project. Shared parameters file can be imported and used in multiple families or projects (Autodesk, 2015). The first and the second parameters are created to host the assessment result of CUI while the 3rd parameter is to exclude building element that should not be considered in CUI calculation such as substructure elements.

5.2.3 Dynamo scripts for Auto CUI tool

As shown in Figure 3 and Figure 4, Auto-CUI tool contains two main scripts developed using Dynamo for Revit. The first script (Quick CUI assessment) is developed to provide the user with a quick assessment of the Concrete Usage Index (CUI) of the building design. This script is designed to track concrete material quantities in each building element and then generate the CUI score and rating in a very short period. During the design stage, a project team could run this script to investigate and compare the impact of several design options on the CUI value. This step is essential because it supports decision-making regarding concrete usage in the building. Once the CUI target is achieved (e.g. GreenRE Gold certification, CUI ≤0.5) the second Dynamo script (Export CUI Report) is executed to generate automatically the CUI report. This script is very similar to the first one, however, it contains additional nodes to export the relevant data to an excel template designed for that purpose.

In more details, the scripts are developed to conform to the rules and elements categorization in Revit. Thus, the first script task is executed in order to select the relevant building elements existing in the BIM model, namely: structural framings (Beams), Structural columns, Floor (slabs), Walls, stairs and roofs (See Figure 3 and Figure 4). Then, the level of each selected element is defined based on its Level parameter. This parameter varies based on each element category in Revit, for instance, the level parameter for beams is 'Reference level', however, for stairs and roofs is 'Base level'. Next, the data of concrete material is gathered from each element using functions such as filtering, sorting, and grouping. Finally, the CUI is calculated by dividing the total concrete volume by the constructed floor area (CFA), and credit allocation logic (see Table1) are used to score the CUI value. At this stage, if the CUI target has been achieved the user is able to execute the second Dynamo script to generate the CUI report.

5.3 Testing and validation

For validation purpose, the developed tool was tested on case study building that consists of an existing office building of four (4) levels and an area of 7500 m². This building is located in the faculty of built

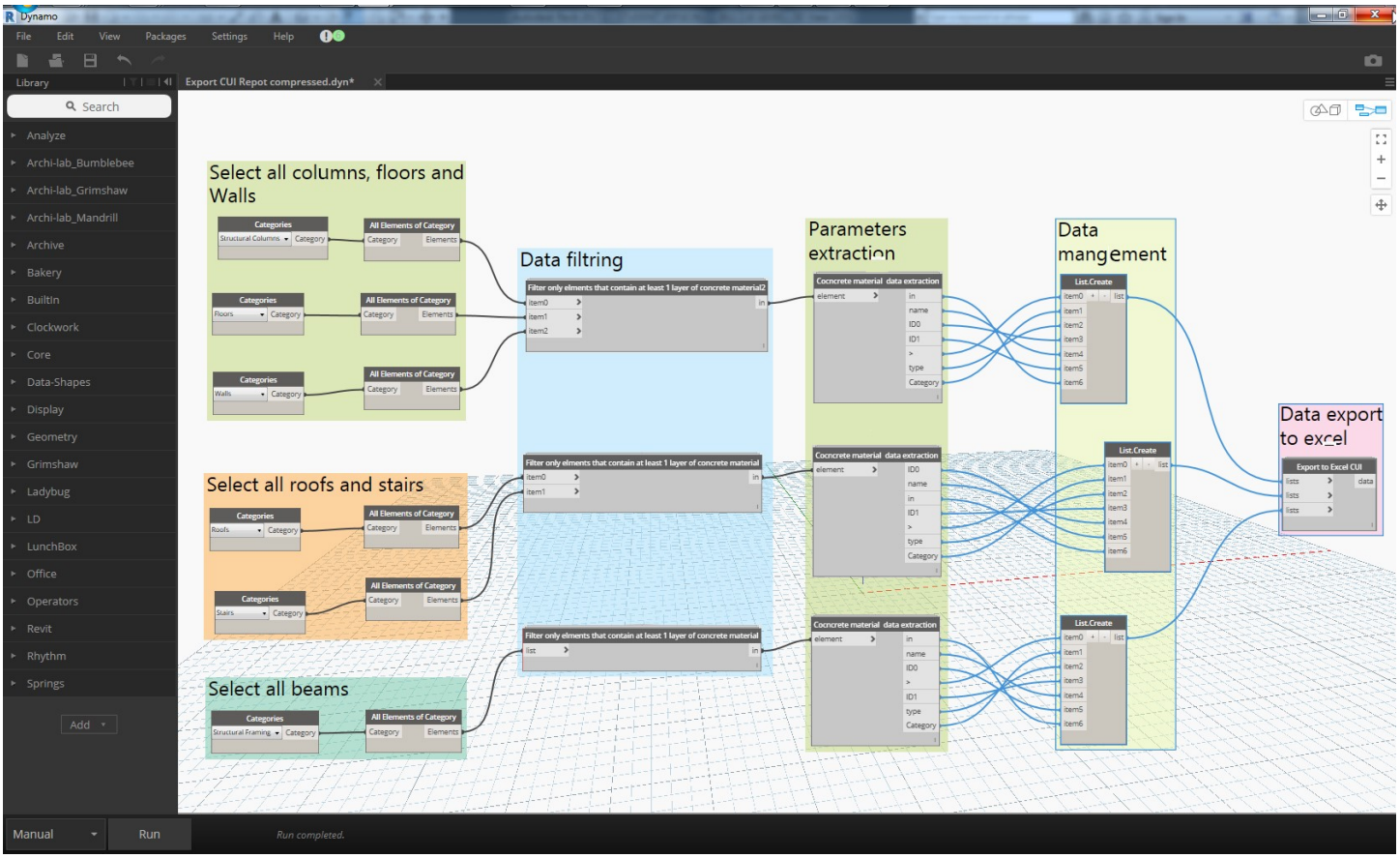

Figure 3: Script for the automation of CUI assessment developed using Dynamo
(For visualization purpose, some nodes in the above script contain several sub-nodes grouped together)

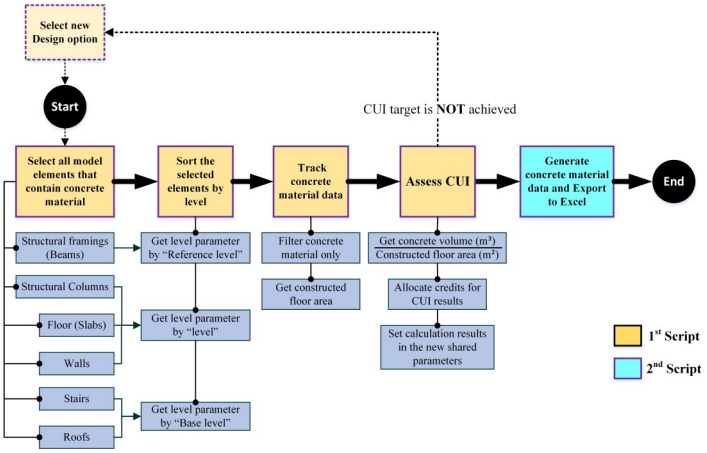

Figure 4 *The logic workflow of the developed Dynamo script for automated CUI assessment*

environment at the University of Technology Malaysia (UTM). The BIM model of this building was modeled by several undergraduate students from the department of architecture based on CAD drawings. It was noticed that the building model was not accurate compared to the existing building. However, it is believed that this will not affect the validation process of Auto-CUI tool. The structure of the building is mainly constructed with a column and beam system with concrete material. The floor slabs and stairs are mainly built of concrete material as well. In contrast, most of the exterior and interior walls are built using a brick material. The demonstration of the workability of the Auto -CUI tool is implemented to this existing case study building. Though, the same process can be used during the design stage.

The assessment process of CUI using the developed tool is very straightforward. When Revit project is open and building materials are assigned to the building elements, the user needs first to run Dynamo Player (Figure 5). When the first script ("Quick CUI Assessment") is executed, the results of CUI and its rating are calculated automatically and shown in the propriety palette in all the views under "Green Building Proprieties"(Figure 5). According to the results, the user is free to take the decision between doing modification in building design to decrease concrete quantities or generate the CUI report in the case where CUI results are acceptable (see Figure 6). This process can be repeated until achieving the targeted CUI score.

Based on the results of Auto-CUI tool, the CUI of this building equals to 0.255m³/m². This value explains a very low concrete

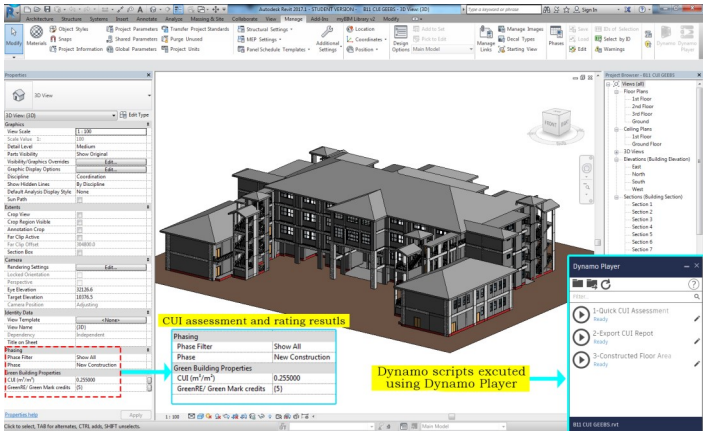

Figure 5 *BIM model of the case study building in Revit*

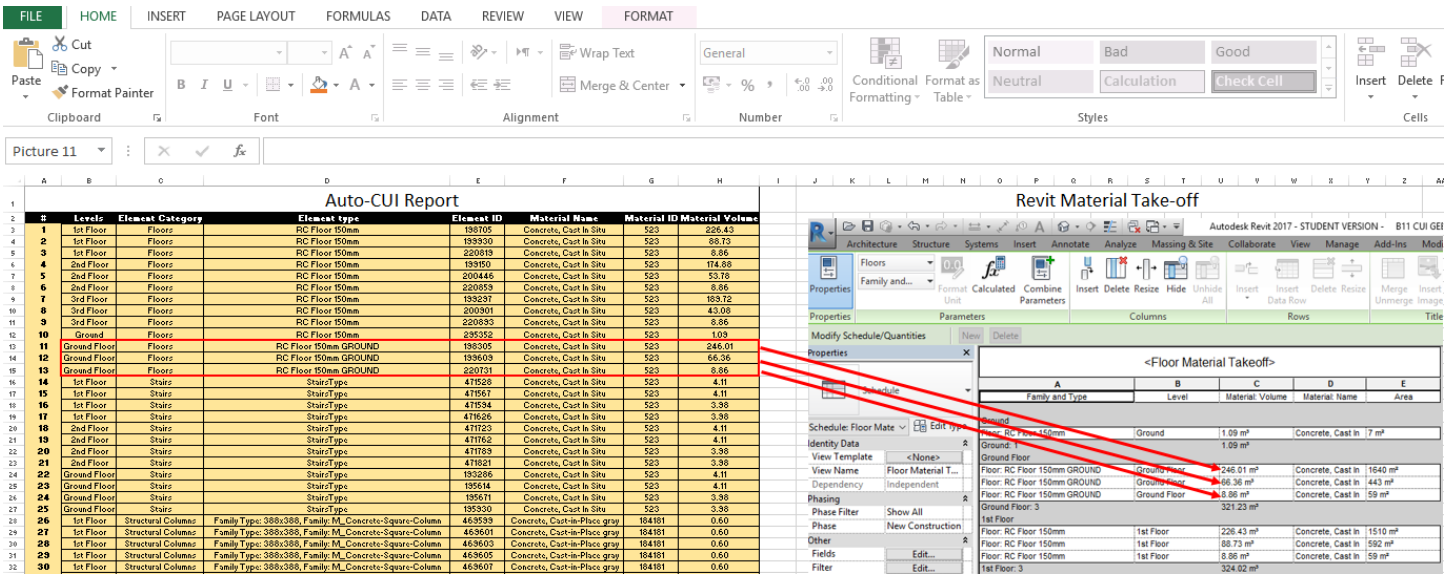

Figure 6 *Sample of detailed comparison of CUI results generated using Auto-CUI report and Revit Material Take-off*

usage in this building which scores 5 credit points (CUI requirement for Platinum certification). In order to validate the results, a Revit Material Take-off based calculation is compared with the results of Auto-CUI tool (see Table 2). The comparison results of each method turn out to be consistent. However, it can be seen that concrete in walls slightly differs in the 2nd floor level of the building. This occurred because one material type could not be filtered by the Material Take-off in Revit. The comparison results of the concrete volumes of the developed tool and Revit Material Take-off are very similar. This is considered natural since Dynamo scripts are designed to handle the same data and rules within Revit API as Material Take-off functionalities do.

CUI assessment using Material Take-off method requires taking extra steps to prepare the schedules (filtering, grouping and sorting functions). Furthermore, the final results of each schedule should be combined manually because in this method building materials are scheduled according to each element category (walls, Floors, stairs… etc.). However, by using the Auto-CUI, the user needs only to run the Dynamo scripts by a click of a button. Data processing in this method may take a few seconds or several minutes depending on the project size, yet, no manual process is required.

During the development and the validation of the tool, some observations have been noticed which may affect the accuracy of the output results. These remarks will be considered as predefined modeling rules for the CUI assessment. Hence before running Auto-CUI tool, the user must follow the following instructions:

- split in each level the elements that span across multiple levels such as walls, columns, and stairs.
- exclude substructure elements from CUI calculation. This can be done using the relevant parameter “Exclude from CUI calculation”

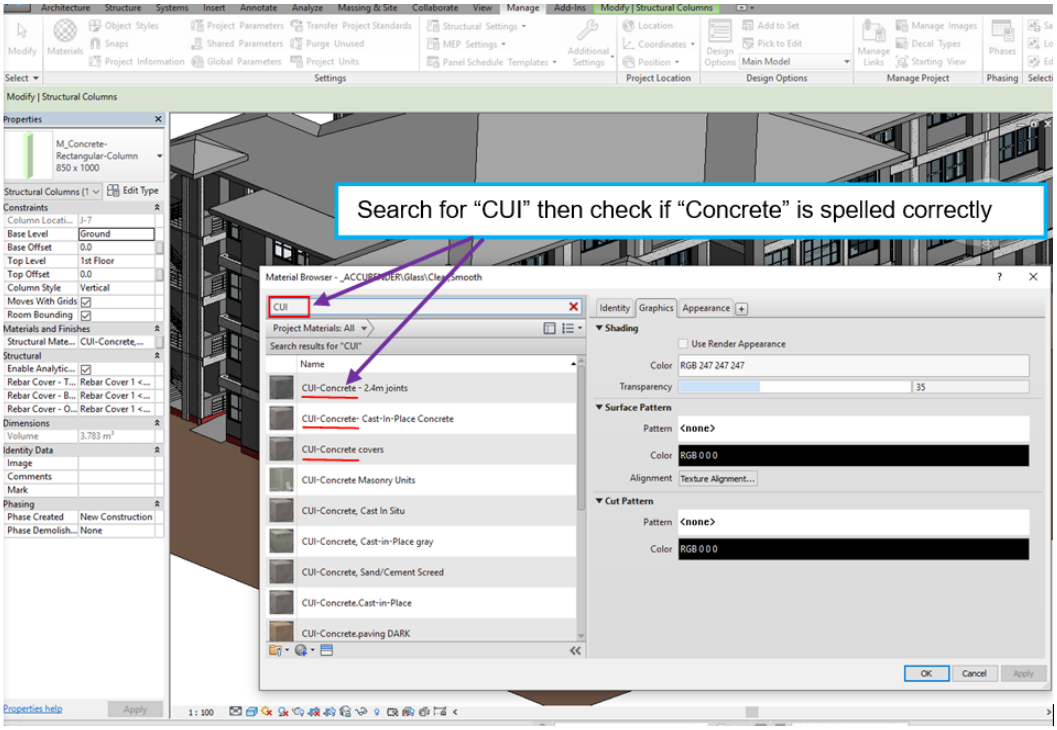

Figure 7 *Using Revit Material Browser to check the spelling of the assigned material in the BIM model*

Table 2 *Overall comparison between the results generated using Revit Material Take-off and Auto-CUI tool of concrete volume based on the building element category and level*

		Concrete Volume (m³)				Concrete Volume (m³)	
Building Level	**Building Elements**	**Revit Material Take-off**	**Auto-CUI Tool**	**Building Level**	**Building Elements**	**Revit Material Take-off**	**Auto-CUI Tool**
Ground + Ground floor	Floors	322.32	322.32	**2nd Floor**	Floors	237.52	237.52
	Roofs	0	0		Roofs	0	0
	Stairs	16.17	16.17		Stairs	16.17	16.17
	Columns	133.5	133.5		Columns	59.09	59.09
	Beams	0	0		Beams	110.56	110.56
	Walls	23.77	23.77		Walls	4.92	5.65
	Total Concrete Volume	**495.76**	**495.76**		**Total Concrete Volume**	**428.26**	**428.99**
1st Floor	Floors	324.02	324.02	**3rd Floor**	Floors	241.66	241.66
	Roofs	0	0		Roofs	0	0
	Stairs	16.17	16.17		Stairs	0	0
	Columns	94.81	94.81		Columns	52.4	52.4
	Beams	143.03	143.03		Beams	115.66	115.66
	Walls	0	0		Walls	0	0
	Total Concrete Volume (m³)	**578.03**	**578.03**		**Total Concrete Volume (m³)**	**409.72**	**409.72**

- check the spelling of the assigned materials in the Revit material editor (one solution is porposed in Figure 7)
- assign building material to the loadable families such as columns in the family editor and not in the project.
- model the Constructible floor area as floor element and not as plate roof.
- check if there are overlapping elements in the project.

6. Discussion

Building designers and architects tend to be just as consumers of many tools that support design workflows and design decision-making. However, nowadays technologies such as computational BIM and visual programming tools have created more opportunities by allowing project teams without programming skills to develop their own tools for design decision support. Auto-CUI tool development is one example showing how the user can become a prosumer instead of a consumer during the design process.

Auto-CUI is easy to use and it requires no coding experience. It will allow the project team to focus more on design ideas instead of hesitating about the concrete usage and its rating score. The developed scripts can be used on many projects and shared with the project team members. This study is a first step in automating sustainability analysis criteria under green building rating tools requirements.

At this level of development, the tool has some technical limitations. For instance, ramp elements are not supported. Hence if a building project contains ramps constructed with concrete material, they will be ignored, thus, their relevant data must be added manually. In addition, in the case where there is more than one type of concrete in the same building element, this may cause errors in the generation of CUI report. All these limitations depend on the capability of Dynamo to interact with Revit API. However, since Dynamo supports Python scripting, it is believed that these limitations can be overcome through code-based scripting within Dynamo scripting environment or by developing a plug -in for Revit.

7. Conclusion

Sustainability analysis related to construction materials require often complex procedures for data collection and assessment. The power of the parametric modeling of BIM tools and the customization capability of visual programming tools have made the automation of repetitive task achievable.

This paper has presented a computational BIM-based workflow for CUI automated compliance-checking. The developed tool is capable of assessing CUI automatically in a very short time and with high accuracy compared to Material Take-off method. This will support design decision-making regarding concrete usage in the building by allowing the project team to test several design options and check if the intended CUI target has been achieved. Moreover, when the CUI goal is reached, the user is able to export the CUI report which clarifies the concrete usage of each building element by floor level. The workflow implemented in this study can be adapted to automate different tasks related to building material usage and impacts during the design stage. For instance, tools for the assessment of materials embodied energy or recycled materials could be developed using similar workflows. Furthermore, this study is considered as a proof of concept that building practitioners are able to develop their own tools using computational BIM and visual programming languages instead of completely relying on commercial tools which are often very expensive.

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An urban governance approach in the development of commercial brownfield: A case study of Iskandar Malaysia

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ABSTRACT

Brownfield development has become one of the sectors to be emphasised imperatively due to emerging greenfield scarcity throughout Malaysia. A brownfield site may have real or perceived contamination issues that require intervention to revive for beneficial use. As of to-date, there is still a number of brownfield sites in Iskandar Malaysia, albeit brownfield revival projects, via planning and policy measures, have been carried out over the years. In this light, a mode of governance is suggested to be a significant factor in the stagnation and success of brownfield development. Therefore, this paper aims to revisit the urban governance modes of brownfield development in Iskandar Malaysia, with a focus on commercial brownfield development. Specifically, two objectives are highlighted in this paper: (i) to assess the site-level success of completed brownfield developments, namely the Paradigm Mall, Skudai and the Danga City Mall, Johor Bahru; and based on the assessment outcomes, it is then (ii) to identify an efficient and suitable mode of governance for commercial use brownfield development. A measuring tool and an indexing scheme to screen brownfield sites were employed alternately. Results show that the Paradigm Mall achieved a higher site-level success compared to the Danga City Mall. Under this light, compared to the corporatist mode of governance, the clientelistic mode of governance with a material objective is highly in relation to a better success of commercial use brownfield development in the background of Iskandar Malaysia. These findings offer valuable messages and insights to practitioners, particularly local policy-makers, that an often-neglected governance mode approach is essential in determining the brownfield development outcome.

1. Introduction

According to various national and regional official documents, such as the National Physical Plan-3, the National Urbanisation Policy-2, the Iskandar Malaysia Comprehensive Development Plan ii 2014-2025 (CDPii 2014-2025), and the Low Carbon Society Blueprint for Iskandar Malaysia 2025, brownfield development has become one of the sectors to be emphasised imperatively due to emerging greenfield scarcity throughout Malaysia. Brownfield development is an enabler to promoting a compact city design, which could contribute to carbon emission reduction by mitigating greenfield encroachment (Majid et al., 2013).

A brownfield site is defined as a derelict or underused site that has been affected by former uses of the site or surrounding land and is predominantly located in fully or partly developed urban areas. A brownfield site may have real or perceived contamination issues posing detrimental environmental and public health risk that require intervention to revive to beneficial use (IRDA, 2014; Pizzol et al., 2016; Liu et al., 2017). At the same time, brownfield stands in contrast to greenfield sites or green open spaces (Ling, 2014), such as undeveloped parcels of forest, farm, or wetlands on the urban fringes (Wedding & Crawford-Brown, 2007; see Onwuayi & Ndinwa, 2017). Brownfield development is usually very complex due to the network of economic, political, administrative and legal apprehension, physical restrictions and diverging social influences (Blokhuis & Schaefer, 2007). As of now, an institutional regime has been exerted within the process of brownfield development due to the changed positions of market parties and their more significant influence on land exploitation. Under this light, brownfield development is not only restricted to be a top-down approach. Instead, it substantially depends on the behaviours and interests of other parties. Therefore, Whitman (2006) suggested that the urban governance of brownfield development has to set on the basis of associating various interests from respective parties, public interest and integration of these considerations with planning based on firm social conscious (see participatory governance). In relation to interdependency between various parties in brownfield developments, an effective and suitable mode of governance is necessary to ensure its efficient process and to achieve a specific objective. Governance could ensure a decision making process to be coordinated within the boundaries of laws and legislation.

With various considerations of brownfield development's requirements and objectives, Blokhuis et al. (2008) defined the urban governance of brownfield development as "the way municipalities lead and direct various approaches within the process based on the interests of all public and private parties involved and the common interest". Moreover, urban governance aims at ensuring a specific result along the brownfield development process. There are several aspects which

are aimed to be achieved, while the most significant ones are as follows: (1) quality of the project, in relation to other policy fields, (2) relation with the programmes and the market, (3) financial dimension and feasibility, and (4) time dimension (Blokhuis et al., 2008). Note that, prior to stating the objective of this paper, authors provide an overview and some background issues of brownfield development in Malaysia.

During the economic crisis in the late 1990s, a large number of abandoned developments (commercial, residential, and industrial) had led to brownfield sites (Ali et al., 2014). To execute brownfield revival, a list of abandoned projects in Iskandar Malaysia was presented by the IRDA (2014) in the CDPii 2014-2025. Moreover, 57 hectares of abandoned buildings and development project sites are demarcated as land suitable for development. The magnitude of benefits from these site developments could be significant. Plans, strategies and policies have also been proposed and implemented to revive brownfield sites.

In view of brownfield development in Malaysia, there are various policies and guidelines which support this approach. The National Urbanisation Policy (NUP) specifies brownfield development as a thrust to mitigate the encroaching urban sprawl upon environmentally sensitive areas. To enable brownfield development, the Federal Department of Town and Country Planning (JPBD) of Peninsular Malaysia has implemented an action plan to realise brownfield development. The authorities take account in identifying and preparing an inventory of brownfield areas, planning and preparing the re-development programmes for brownfield areas, and providing incentives for the re-development of brownfield areas as commercial and special industrial zone. Other than that, the Brownfield Development Guideline by the JPBD (2012) suggested that brownfield developments are based on several principles, namely the sustainable use of natural resources and compliance to law and existing guidelines. The JPBD (2012) also proposed general guidelines in directing brownfield development for government officials, such as identifying criteria of brownfield areas, specifying types and acquisitions land ownership, identifying heritage value sites or buildings, implementing site assessments and designing elements for rebuilding a brownfield area. In the CDPii 2014-2025, brownfield development needs to be emphasised as it is a potential environmental resource to contribute to economic growth and environmental preservation. In light of urban governance, it is proposed that the IRDA and local authorities shall identify and prepare a development guide plan to facilitate brownfield development progress. Next, the IRDA and local authorities shall provide technical advisory and development incentives for redevelopment on brownfield and greyfield sites. Other than that, the IRDA suggested that each local authority has to undertake a detailed study and a development strategy plan for abandoned projects in Iskandar Malaysia, and this is the step prior to preparing a development guide plan for brownfield development. The NUP, the Brownfield Development Guideline, and the CDPii 2014-2025 share consensus, in terms of the directions and policies of brownfield development. Local authorities/governments are recognised as the enabler for brownfield development as they have to identify adequate and suitable brownfields for development. Moreover, government officials are to provide incentives to boost brownfield development. These approaches indicate the importance of substantial and active participation of government officials in brownfield development during an initial planning stage.

A number of brownfield sites remain undeveloped in Iskandar Malaysia, despite brownfield revival projects via related action plans, strategies, and planning policies, have been carried out over the years (IRDA, 2014). In addition, the list of abandoned projects in Iskandar Malaysia is found to be unaligned with the current circumstances as several statuses of abandoned buildings which are indicated as "revived" remain undeveloped. For instance, the Pacific Mall, which was announced as purchased by a new owner, namely Mahabuilders in 2013, is classified as "revived", but in reality, it remains abandoned without any development works on-site. Such stagnant brownfield development projects have caused a discrepancy on the list of abandoned projects in Iskandar Malaysia.

This matter could be due to various reasons, such as financial difficulties faced by the owner, unexpected bad economic conditions, inadequate project feasibility studies, unfavourable policy and lack of cooperation from local authorities (Yap, 2010). Nonetheless, a mode of governance is suggested to be a significant factor in the stagnation of brownfield development (Blokhuis, 2008; Liu et al., 2017). Irrespective of the above claim, research related to application and understanding of governance modes in brownfield development is still limited (Zielke & Waibel, 2016; Liu et al., 2017); thus, more studies are required, and this empirical paper can be deemed timely towards contributing to environmental politics discussions. According to DiGaetano & Strom (2003), the modes of governance is defined as a political system, which is the linkage of political institutions and informal arrangements of each city. To distinguish the mode of governance in a particular city, informal political relationships are required to be identified. Firstly, governing relations are to be considered. They are the modes of interaction and interdependency between public and private sector (economic and social) interests. Secondly, governing logic is about an approach or method in arriving at political decisions (e.g., via consensus building and reciprocity). Thirdly, the key decision makers play crucial roles. Politicians, bureaucrats, and agents of various civic (economic or community) could be considered as decision makers based on their relative interests. Lastly, political objectives, covering material (selective tangible benefits), purposive (nonselective tangible benefits), and symbolic (nontangible benefits), can be influential as well. Based on the above governance characteristics and criteria, among others, two modes of governance have been identified, namely clientelism and corporatism (see more in DiGaetano & Strom, 2003). The modes above are not necessarily in a pure singular form; mixed/ hybrid governance modes (e.g., both clientelism/corporatism) with different degrees may coexist in an institutional system.

The clientelistic modes of governance develop exclusive, personalised exchange relationships between politicians (patrons) and favoured interests and clients (e.g., private sectors and the general public) (Stokes, 2007). The governing logic relies on a pragmatic reciprocal exchange, whose primary purpose/objective is material, that is, selective benefits or goods and services (e.g., financial resources, facilities and assistance in the forms of economic security and protection, political votes and supports, city image and reputation) are involved during the exchange between the politicians and clients. For instance, when governments provide certain benefits and services to their clients, certain return of political votes or supports are expected from the beneficiary. Under the reciprocity nature of an exchange (i.e., mutual agreement), both politicians and clients are considered as key decision-makers. While, for the corporatist mode, it forms programmatic, instead of pragmatic, public-private governing relations, in which modes of interaction between politicians and powerful civic elites are based on exclusionary negotiation and compromise (DiGaetano & Strom, 2003). The key corporatist governing logic is to build and obtain a consensus on governing tasks and tends to result in the formation of ruling coalitions of economic and community interests. The objective of this corporatist mode is mainly purposive (i.e., nonselective tangible benefits). The benefits gained under this urban corporatism may not as specific (personalised) as the clientelism,

whereby the former purpose generally associates with the wellbeing and interest of a city or a country involving revitalisation of a degraded city and recovery of a country's economic downturn (see more in DiGaetano & Strom, 2003).

Therefore, based on the above considerations plausibly associating urban governance with success and sustainability of brownfield development, this paper aims to revisit the urban governance modes of brownfield development in Iskandar Malaysia, Johor Malaysia, with a particular focus on commercial use brownfield development. The Paradigm Mall, Skudai and the Danga City Mall, Johor Bahru were selected as case studies due to their commercial use after redevelopment. The objective of this paper is (i) to assess site-level success of completed brownfield developments and thus (ii) to identify an efficient and suitable mode of governance for commercial use brownfield development in Iskandar Malaysia.

The paper is structured as follows. Section 2 begins with methods, in which it provides descriptions and background of two study areas (cases: the Paradigm Mall and the Danga City Mall) within Iskandar Malaysia. It then continues with the measurement of site-level success in brownfield developments, in which a methodology or tool of assessing the sustainable brownfield redevelopment by Wedding & Crawford-Brown (2007) and an indexing scheme by Chrysochoou et al., (2012) covering measurement dimensions are explained. While a detailed set of results and findings is presented in section 3, discussions of the results are shown in section 4. Finally, section 5 presents the conclusions, implications and recommendations of the research.

2. Methodology

2.1 Description of study area

2.1.1 Paradigm Mall

The Paradigm Mall is a shopping mall with a commercial use that has just opened to the public since 28 November 2017. It was developed by WCT Hartanah Jaya Sdn. Bhd., a subsidiary of WCT Holdings Bhd. According to WCT Hartanah Jaya Sdn Bhd. (2017), the Paradigm Mall is 7-storey high with 1.3 million sq. ft (13 acres) in net retail space. Situating along Jalan Skudai, the mall is a part of a carefully-crafted 13-acre, integrated development. This integrated development will later include a proposed 296-room hotel and a 24-storey serviced apartment.

This site was previously located with the Kemayan City. It was a commercial use development which was abandoned before its completion of construction since 1998 until the construction works of the Paradigm Mall started. The original plan of the Kemayan City established in 1993 stated it would be the largest single integrated shopping complex in Johor Bahru and was estimated to worth RM400 million (Ali et al., 2014). Since its abandonment, the site of the Kemayan City was categorised as "Brownfield Category D", i.e. an abandoned development project that is not completed within the implemented construction period and is abandoned from construction for more than ten years (JPBD, 2012).

According to the JPBD (2012), main factors causing this type of abandoned development are due to financial issues and failures to acquire approval from a politically dominant party. With respect to the Kemayan City, its condition reflected what was mentioned by the JPBD, which it was abandoned due to economic the crisis in 1998 (Ali et al., 2014). When the Kemayan City was abandoned, its construction works were 90 percent completed, and loans from the finance company (Idaman Usahamas Sdn. Bhd.) for this development were not settled.

The following presents a brief interlude to the history of the chosen case study.

"Interlude": The B8 Mall Shopping Centre.

After more than ten years of abandonment, the Kemayan City was acquired by Blackstone Group Eight Sdn. Bhd., a subsidiary company of Allstonesgroup. According to the ex-Johor State Chief Minister, the Kemayan City would be restored under the management of Blackstone Group Eight Sdn. Bhd. Various parties including the local authority, Johor Bahru City Council (MBJB) assisted in the procedure to restore this abandoned building. Based on the redevelopment plan, it was planned to start the site works in the mid-2011 and was envisioned to develop it into a contemporary shopping centre and a hotel, namely the B8 Mall Shopping Centre. The construction works were expected to be completed by the end of 2013 (Suratman & Ali, 2012). During that time, Black Stone Eight Sdn. Bhd. was up to the stage of Sale and Purchase Agreement to purchase this development project in 2010. However, the later part of the planning permission process stagnated, particularly on the matter of the alteration of the height and types of development to deem fit the planning requirement of new development. Moreover, this redevelopment plan was not realised due to financial issues. After that, the Kemayan City remained as an abandoned building with deteriorating conditions.

2.1.2 Danga City Mall

The Danga City Mall is a revived development project listed by the HBA (National House Buyers Association) as of 2009. It occupies a gross built-up area of 1 million sq. ft and 500,000 sq. ft nett lettable space with 7 storeys high. Located along Jalan Tun Razak, this site was previously situated by the Plaza Best World. It was built in the mid of 1980s with a cost of RM240 million, and its construction operation was commenced in 1996. However, the Plaza Best World stopped operating after two years due to the 1997 financial crisis (HBA, 2009). After the abandonment of the Plaza Best World, the site was categorised as "Brownfield Category C" as it was abandoned after the completion of construction works and operation (JPBD, 2012).

2.2 Measurement of Site-Level Success in Brownfield Developments

To evaluate site-level success in brownfield developments of the Paradigm Mall and the Danga City Mall, a measuring tool proposed by Wedding & Crawford-Brown (2007) and an indexing scheme to screen brownfield sites by Chrysochoou et al. (2012) were utilised alternately. There are various tools and schemes to measure achievement of brownfield development proposed by a number of authors (Bacot & O'Dell, 2006, Wedding & Crawford-Brown, 2007; Chrysochoou et al., 2012; Pizzol et al., 2016; Zhu et al., 2015). However, the elements used in these tools and indexing schemes could be varying to a different extent due to different viewpoints from stakeholders.

Nevertheless, variables of these brownfield development indexing schemes comprise four dimensions generally, namely socio-economic, environmental, liveability, and financial (Chrysochoou et al., 2012). Therefore, one crucial reason to employ the two indexing schemes by Wedding & Crawford-Brown (2007) and Chrysochoou et al., (2012) is due to their high consensus in addressing variables according to these four dimensions.

Based on literature review, the former measurement scheme by Wedding & Crawford-Brown (2007) corresponds to this paper more than the latter (i.e., Chrysochoou's et al., 2012 tool) in terms of dimensions and variables. The assessed variables of the former indexing scheme are also more comprehensive than the latter. However, the

indexing scheme by Chrysochoou et al., (2012) posited the need for a methodology to assess the variables quantitatively, which is deemed lacking in the former scheme. As a result, this paper adopted the two indexing schemes to assess the site-level success of brownfield developments quantitatively and comprehensively.

2.2.1 Sustainable Brownfields Redevelopment (SBR) Tool

In the paper by Wedding & Crawford-Brown (2007), the authors developed the Sustainable Brownfields Redevelopment (SBR) Tool with selected indicators. Hence, indicators that developed the SBR Tool are crucial as they affect the success level of brownfield developments. In light of determining indicators to formulate the SBR Tool, the authors surveyed with a sample size of 13 various experts to seek their professional views in relation to variables of a brownfield indexing scheme. As a result, the variables could be categorised into four groups, namely environment-health, finance, liveability, and social-economic.

2.2.2 Indexing Scheme to Screen Brownfields

Chrysochoou et al., (2012) proposed this indexing scheme to screen a large number of brownfields with regard to their abilities in creating revenue after redevelopment. This indexing scheme is mostly useful to detect the suitability of brownfields for redevelopment, and it partly adopted the variables of the Sustainable Brownfields Redevelopment (SBR) Tool by Wedding & Crawford-Brown (2007). This scheme implies three dimensions which are socioeconomic, smart growth and environmental. Each of the three dimensions is indexed based on the location-specific variables regardless of the target end use (Chrysochoou et al., 2012). Therefore, population density, property values and unemployment represent socioeconomic variables due to their potential in contributing economic growth to brownfield development. On the other hand, the smart growth or liveability index was developed by the LEED for Neighbourhood Development (LEED-ND), which is a rating system that integrates the principles of smart growth, urbanism and green building into a national system for neighbourhood design by the U.S. Green Building Council. Lastly, an environmental dimension is associated with variables such as the potential source of contamination (past use), a pathway of exposure (soil permeability) and receptors (zoning, open spaces, etc.).

2.2.3 Dimensions of Measurement

Reposed on the basis of the two selected indexing schemes, the site-level success of brownfield developments was measured based on the four dimensions, namely socio-economic, environmental, liveability, and financial. The measurement of these dimensions was mainly based on secondary (statistical) data, which were then triangulated and supplemented with primary data (i.e., brief semi-structured interviews with government officials, property developers, and tenants). The methods of index assessment are also presented as follows.

The socio-economic index consists of an increase in population, an increase in mean household income and an increase in surrounding property values (houses). These variables are assessed with secondary data, such as the Draf Rancangan Tempatan Daerah Johor Bahru & Kulai 2025, the CDPii 2014 – 2025, the Property Market Report First Half 2017. In order to determine the increase of variables quantitatively, relevant data of before and after brownfield development were collected, and they were assessed to show a particular variable's increment in percentage.

Taking increase in mean household income as an example, the mean household income surrounding the Paradigm Mall was RM 4,463 as of 2012 according to the Draf Rancangan Tempatan Daerah Johor Bahru & Kulai 2025. While, the mean household income was RM7,539 as of 2017, and this was the latest data after the erection of brownfield development at this particular site. Based on these figures, the increase of mean household income is 68.92%. According to the assessment method proposed by Chrysochoou et al. (2012), the percentage of increment of each variable is classified based on the range of percentage.

Next, the environmental index consists of the past use of a site and the percentage of decrease in green space on the site. These variables were assessed with literature review and the MODIS Collection 6 Land Products Global Subsetting and Visualization Tool, respectively. The past uses of selected sites were identified by various literature review. Besides, in order to determine the percentage of decrease in green spaces quantitatively, the Enhanced Vegetation Index (EVI) of the site before and after brownfield development was collected with the MODIS, and they were assessed to obtain its percentage of decrease.

For instance, the EVI of the site before the Danga City Mall erected was 0.42, and this index was recorded in 2002. While, the EVI at the site upon completion of the Danga City Mall was 0.30 in 2008. Based on these figures, the decrease in green space of the site was 28.57%. Based on this result, it could be classified under the group of 26 – 50%, in which a score for this variable dedicated to the Danga City Mall could be assigned.

The liveability index comprises the proximity to a restaurant/grocery store, proximity to green space, and proximity to a transit station. These variables were assessed using the Google Earth application. After obtaining the spatial data of proximity to a restaurant/grocery store, green space and a transit station, they were classified and scored according to the classifications and scores as shown in Table 1. For example, proximity to a green space from the Paradigm Mall is detected to be 427.58m. Based on this result, it could be classified into the group of 400 – 800m radius. After classification, the score of this particular variable could be assigned as 2.

Lastly, the financial index comprises the percentage of an increase in site property value, the length of time (from purchase to occupancy), and the rent premium of redevelopment. These variables figures were sourced from various primary and secondary data. Firstly, the method to assess the increase in site property value is similar to the assessment of an increase in mean household income as discussed previously. Next, the length of time (from purchase to occupancy of a property) is assessed using various literature review, and they were then classified according to the classification as shown in Table 1.

For example, the length of time (from purchase to occupancy) for the Paradigm Mall was detected as five years (2013-2017). Based on this result, it could be classified into the group of 5 – 6 years. After classification, the score of this particular variable could be detected as 1. Lastly, the rent premium of redevelopment was identified with various sources, and the result is presented as an amount of value per unit (square feet). As the unit remains unchanged, the figures of this variable were encoded as a scalar.

Each of the index/dimension classifications is dedicated to a respective score. Table 1 shows all the four indexes composing respective variables and their classifications in relation to scores.

3. Results and findings

After understanding the variables involved and methodology with respect to classifications and scores assignation, site-level success in brownfield developments of the Paradigm Mall and the Danga City Mall were assessed with the four dimensions, i.e., socio-economic, environmental, liveability, financial indexes as mentioned by Wedding

Table 1 *Variables, classifications, and scores of the four indexes (Socio-economic, environmental, liveability and financial)*

Socio-economic Index Variables	**Classifications**	**Scores**
Increase in population	> 100%	5
	76 – 100%	4
	51 – 75%	3
	26 – 50%	2
	0 – 25%	1
Increase in mean household income	76 – 100%	4
	51 – 75%	3
	26 – 50%	2
	0 – 25%	1
Increase in surrounding property values (houses)	> 100%	5
	76 – 100%	4
	51 – 75%	3
	26 – 50%	2
	0 – 25%	1
Environmental Index Variables	**Classifications**	**Scores**
Decrease in green space on site	0 – 25%	4
	26 – 50%	3
	51 – 75%	2
	76 – 100%	1
Past use of site	Industrial	3
	Commercial	2
	Residential	1
Liveability Index Variables	**Classifications**	**Scores**
Proximity to restaurant/grocery store (meter)	Below 400m radius	3
	400 – 800m radius	2
	Above 800m radius	1
Proximity to green space (meter)	Below 400m radius	3
	400 – 800m radius	2
	Above 800m radius	1
Proximity to transit station (meter)	Below 400m radius	3
	400 – 800m radius	2
	Above 800m radius	1
Financial Index Variables	**Classifications**	**Scores**
Increase in site property value	751 – 1000%	4
	501 – 750%	3
	251 – 500%	2
	0 – 250%	1
Length of time (from purchase to occupancy)	1 – 2 years	3
	3 – 4 years	2
	5 – 6 years	1
Rent premium of redevelopment	Scalar (Mean Value)	Scalar

Source: adapted from Wedding & Crawford-Brown (2007) and Chrysochoou et al., (2012)

& Crawford-Brown (2007) and Chrysochoou et al., (2012). The overall results of the site-level success are presented in Table 2 below.

Based on the assessment of the site-level success of brownfield developments, the brownfield development of the Paradigm Mall is identified to be more successful than the Danga City Mall. Their scores are 31.5 and 29.5 respectively (as shown in Table 2). Compared to other variables that the Paradigm Mall and the Danga City Mall have similar results (scores), e.g., under the financial index of rent premium with about RM1 difference/sf between the two malls, the most prominent difference observed is the socio-economic index variable that covers population increase (with the scores 5:1) and the increase of mean household income (with the scores 3:1), respectively. To make the above result more inferentially meaningful, this paper subsequently shows a relationship between the site-level success and their modes of governance. In view of determining a mode of governance of selected case studies for both the Paradigm Mall and the Danga City Mall, the terminologies of modes of governance posited by DiGaetano and Strom (2003) above were embedded to serve as a precept. Table 3 shows different governance modes adopted by the malls.

After the unsuccessful development plan of the B8 Mall Shopping Centre, in 2013, WCT Hartanah Jaya Sdn Bhd entered into a conditional sale and purchase agreement with Idaman Usahamas Sdn Bhd (a subsidiary of Malaysia Building Society Bhd., MBSB) for the acquisition of the idle building. Finally, WCT Hartanah Jaya Sdn Bhd purchased this abandoned building with RM180 million after a competitive tender process. As of to-date, this brownfield development project initiated by WCT Hartanah Jaya Sdn. Bhd. is successful with the operation of the Paradigm Mall as an indicator

In this development project, the state and local authorities (e.g., the Department of Environment, DOE, the Town and Country Planning Department, JBPD, state and local authorities) and the developer acted as crucial parties during the initial stage. The DOE was to categorise and identify the brownfield site. Subsequently, the developer planned for the development project, and the approval of planning permission was subject to the state and local authorities. However, after the approval of planning permission was granted, the developer became the key party to implement this development plan. Moreover, the daily management of the Paradigm Mall is taken charged by various division of departments. For instance, the developer has appointed Kuala Lumpur Pavilion Sdn. Bhd. as the retail manager of the Paradigm Mall (WCT, 2017). Consequently, this development has been an entrepreneurial project initiated by an investor, and the decisions are made by various state and local authorities. Apparently, the objective of this development project is materialistic-oriented. Local authorities and the investors have a reciprocity relationship. Therefore, such clientelistic mode of governance with a material objective was observed, and this governance mode is based on a pragmatic exchange/ agreement between the local authorities (for political support and the city's image making) and investors (for maximising commercial success and profits).

Next, for the case of the Danga City Mall, due to the development launching of Iskandar Malaysia, the local council (MBJB) is envisioned to mitigate abandoned buildings and encourage brownfield development to promote the city image. Hence, the local council offered incentives to developers who were interested in reviving existing abandoned buildings. Under this premise, the Plaza Best World was purchased by MFI Equity Sdn. Bhd. which was a vehicle used by Ekovest Bhd to purchase the complex for RM50 million from Pengurusan Danaharta Nasional Bhd in 2004. Limbongan Ekovest Management Sdn Bhd (LEM), which is 49 percent owned by Ekovest Bhd. was appointed to be the project manager for the Danga City Mall development (Musa, 2004).

Before the Danga City Mall opened to the public, the anchor tenant of this mall, i.e., Metrojaya Sdn Bhd. announced to invest in this mall with RM10 million. This announcement and the signature of the agreement were witnessed by the ex-Johor State Chief Minister. Yet, the state government does not seem to manage the daily operations of the mall. A dedicated department, namely the Danga City Mall Management is responsible for it. In this case, the state government was witnessed to participate in this development substantially, specifically from the uptake of the previously abandoned building by a new owner until the facilitation of tenants. The high participation of the state government could be due to its good relationship with the new owner of the Danga City Mall, Ekovest Bhd (urban elites). In this instance, the primary corporatist mode of governance, with a slight degree of clientelism (secondary mode), could be observed. The governing relation of "exclusionary negotiation and compromise" is heavily and solely driven by the state government's agenda and purpose on the development of Iskandar Malaysia via the revival project of the Danga City Mall.

Table 2 *The Site-Level Success Measurement and Results of Brownfield Developments for the Paradigm Mall and the Danga City Mall*

	Paradigm Mall, Skudai				**Danga City Mall, Johor Bahru**			
Variables	Data	Increment	Classifications	Scores	Data	Increment	Classifications	Score
Socio-economic Index								
Increase in population	390,888 (2000) 868,739 (2015)	122%	> 100%	5	433,624 (2000) 541,508 (2010)	24.88%	0 – 25%	1
Increase in mean household income	RM 7,539 (2017) RM 4,463 (2012)	68.92%	51 – 75%	3	RM 5,197 (2012) RM 4,463 (2012)	16.45%	0 – 25%	1
Increase in surrounding property values (houses)	RM324.68/sf (2017) RM188.31/sf (2000) *Taman Munsyi Ibrahim*	108.02%	51 – 75%	3	RM438.46/sf (2017) RM219.23/sf (2000) *Taman Century*	100%	76 – 100%	4
Environmental Index								
Decrease in green space on site (EVI)	0.63 (2001) 0.19 (2017)	69.84%	51 – 75%	2	0.42 (2002) 0.30 (2008)	28.57%	26 – 50%	3
Past use of site	Commercial	-	Commercial	2	Commercial	-	Commercial	2
(cont.) Variables	**Paradigm Mall, Skudai**				**Danga City Mall, Johor Bahru**			
	Data	Increment	Classification	Score	Data	Increment	Classification	Score
Liveability Index								
Proximity to restaurant/ grocery store (meter)	300 (nearest grocery store)	-	Below 400m radius	3	486.3 (nearest grocery store)	-	400 – 800m radius	2
Proximity to green space (meter)	427.58	-	400 – 800m radius	2	689.49	-	400 – 800m radius	2
Proximity to transit station (meter)	848.83	-	Above 800m radius	1	305.17	-	Below 400m radius	3
Financial Index								
Increase in site property value	RM180 mil (purchase) RM1.5 bil (development)	733%	501 – 750%	3	RM50 mil (purchase) RM455 mil (development)	810%	751 – 1000%	4
Length of time (from purchase to occupancy)	5 years (2013 – 2017)	-	5 – 6 years	1	4 years (2005 – 2008)	-	3 – 4 years	2
Rent premium of redevelopment	RM6-7/sf	-	6.5	6.5	RM5-6/sf	-	5.5	5.5
TOTAL				31.5				29.5

Table 3 *Comparison of Brownfield Developments Governance between the Paradigm Mall and the Danga City Mall*

	Paradigm Mall, Skudai	**Danga City Mall, Johor Bahru**
Size (sq. ft)	1.3 mil	1 mil
Name of previous project	Kemayan City	Plaza Best World
Beginning status of abandonment	1998	1998
Purchased by new developer (End status of abandonment)	2010, 2013	2004
Operations since	2017	2008
Land use	Commercial	Commercial
Developer	WCT Hartanah Jaya Sdn. Bhd.	MFI Equity Sdn. Bhd. (subsidiary of Ekovest Bhd.)
Price to purchase	RM180 mil	RM50 mil
Governance consideration/mode	Clientelistic	Corporatist (primary)
Governing logic	Reciprocity	Consensus building (majority-based)
Objective	Material	Purposive (1st), Material (2nd)
Measurement of Site-Level Success of Brownfield Developments	31.5	29.5

4. Discussion

The site-level success of brownfield developments of the Danga City Mall is identified to be lower than the Paradigm Mall although both of them are brownfield development projects and are dedicated for commercial use. This difference is resulted from various variables as stated in the assessment of success level measurement in this paper. Most importantly, the urban governance modes of these brownfield developments are different based on the case study (as shown in Table 3). The modes of governance are crucial for the way how the government (local, regional and national) and stakeholders plan, finance and manage urban areas (Avis, 2016). Hence, this paper calls for an emphasis on the mode of governance to improve the success level of brownfield development.

Based on the case study, the clientelistic mode of governance implied by the Paradigm Mall leads to a better success level. The development of the Paradigm Mall has been an entrepreneurial project of an investor, and the decisions are made by respective departments. For instance, WCT Malls Management Sdn. Bhd is a subsidiary team of WCT Land Sdn. Bhd to manage the mall and Kuala Lumpur Pavilion Sdn. Bhd is appointed to be responsible for the position of retail manager. On the whole, the Paradigm Mall's objective to maximise commercial success (i.e., profit gaining from the developer side) is apparent, which in return favours the city-image making for the ultimate purpose of the government's political reputation and support. As a result, a win-win situation is achieved. Thus, the clientelistic mode of governance with a material objective is adequately in line with its aim for commercial success maximisation, and the outcome is positive.

On the other hand, the Danga City Mall is rated lower in the measurement of site-level success of brownfield developments. As a commercial use shopping mall, its origin to revive the building was fundamentally and predominately rooted in the state government's purposive agenda on the development of Iskandar Malaysia with unspecified/general tangible benefits, which may compromise the private sector (developer) incentives in the long run for effective management. More precisely, the development objective of Iskandar Malaysia has been observed undoubtedly since the operation of the previously abandoned building (the Plaza Best World) and is continued with the current mall. However, the monotonous retail services in this mall managed by the disincentivised management group, as a result of the negotiation and compromise basis, could degrade its attractiveness to the public. Its lower success level might be due to its lacking and insufficiency of the material selective oriented mode of governance, despite the mall's secondary clientelistic governing mode (see the hybrid mode by DiGaetano & Strom, 2003). As a commercial use building, these factors (governing logic and more materialistic objective) are crucial to lead to, and more vitally, sustain commercial success maximisation.

5. Conclusion and recommendations

In conclusion, compared to corporatist governance, the clientelistic mode of governance with a material and pragmatic (profit-oriented) objective fits in, and is highly in relation to, a better success level of commercial use brownfield development in the case of Iskandar Malaysia. This paper suggests that a stagnant, low success level of brownfield development could be due to the inappropriate approach of an urban governance mode. More precisely, the paper adds interesting discussions and lessons learnt to the field of urban planning and management, specifically on commercial brownfield development, that, in the Iskandar Malaysia case, the governance mode of corporatism is seemingly effective in the short run in governing and managing the brownfield development and is more advantageous to the governments for their general purposive (community and economic interests) objective. To sustain the effective management of commercial brownfield development, where private sectors' effective, long-term management is one of the key critical success factors, their selective, specific incentives (profit-making) should not be compromised during the exchange, and wherever possible their management process should not be hindered or burdened with high transaction costs, instead it can be willingly facilitated by the government, and this is called clientelism. These empirical findings and evidence also offer valuable messages (awareness) and insights to practitioners, particularly local policy-makers and local authorities (e.g., land officers and town planners), that an often-neglected sustainable urban governance approach is a *sine qua non* in determining the brownfield development outcome.

Note that it would be premature to conclude that this paper alone can solve the entire aforesaid brownfield stagnation issues, in particular using mainly secondary data from online sources and news, and few brief semi-structured interviews above which could be deemed less comprehensive. However, this paper, via the governance concept, may provide sufficient understanding to shedding light on this abandoned brownfield issue. Therefore, for future research and better results validity, more comprehensive governance and management study covering other modes of governance (e.g., managerial, pluralist, and populist) via more extensive semi-structured interviews and questionnaire surveys that involve the identification and formulation of potential brownfield development solutions should be conducted to produce a liveable, sustainable city environment. This move is essential as not only is it in line with the New Urban Agenda, it contributes to achieving the Sustainable Development Goals (SDGs), especially SDG 11 on sustainable communities and cities.

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Perspectives on issues and the application of the innovative procurement approaches for the Industrialised Building System (IBS)

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ABSTRACT

Malaysia is making an aggressive effort of transformation to become a fully developed country. As one of the pillars for transformation, the construction industry has been undergoing a major reform with regard to the traditional method of construction. In recent years, the Industrialised Building System (IBS) has been promoted extensively with the government taking a lead with the practice. Studies showed that IBS has been able to expedite construction process, improve the time taken to accomplish a project, improve building quality, able to control cost and human resources, which in overall, raise occupational health and safety standard of construction. Despite, as most IBS projects were carried out under the traditional procurement method, the full benefits of IBS are somehow obscured. Several issues such as work delay, lack of communication and integration, lack of knowledge and increase in cost, which are synonymous to the traditional procurement method appear to outweigh the benefit of IBS. Hence, this research aims to suggest an alternative to the traditional procurement method with regard to IBS project implementation. The focus of this research has been on the challenges and innovative procurement methods most suited for IBS project. Two objectives were outlined: (1) to identify issues faced by client on current procurement method in IBS project; and (2) to identify the client's perspective on innovative procurement method most suited for IBS project. Data for this research was collected through semi-structured interviews with five respondents from five major developers having experience in IBS project implementation. The results from the thematic analysis revealed that apart from the common issues which ascend from the sequential nature of the traditional procurement method, design integration issue was opined to aggravate the situation. Unanimously, respondents agreed that partnering is the way forward for IBS project implementation in Malaysian construction industry. This research contributes by providing important pointers for the local construction industry to move forward with IBS project implementation.

1. Introduction

The construction sector is growing rapidly and has been subjected to numerous transformation program with regard to the traditional method of construction. In recent years, the Industrialised Building System (IBS) has been promoted extensively with the government taking a lead with the practice. IBS can be described as a method to construct a building by using prefabricated components. The components are manufactured systematically using machinery and mould in the factory and then transported and assembled on site (Rahim & Qureshi 2018).

The Malaysian government had pushed the concept of IBS through several policies such as IBS Strategic Plan, IBS Roadmap 2003-2010 and IBS Roadmap 2011-2015. Despite the efforts, the implementation of IBS in private project seemed low. Studies showed that the current traditional procurement method appear to be inadequate and had contributed to longer completion period, project delay, increasing the final cost of project and variation works. For this reason, an innovative procurement method appear to be the solution to address the current concern.

According to Construction Industry Development Board (CIDB), IBS has been introduced to solve issues of productivity. Studies showed that IBS has been able to expedite construction process, improve the time taken to accomplish a project, improve building quality, able to control cost and human resources, which in overall, raise occupational health and safety standard in construction. Though, there are many clients who do not satisfied with the completion time for traditionally procured IBS projects. This is attributed to the time needed for the design, where construction could only be commisioned after the completion of this stage.

Poor integration and communication between construction parties is the scenario that happens in the construction industry today (Mohd Fateh & Mohammad 2017). Cooperation among construction parties is one of the important aspects that will contribute to the success of IBS projects. The separation between construction players and work formed a silo condition which contributed to conflict and misunderstanding.

As most IBS projects were carried out under the traditional procurement method, the full benefits of IBS are somehow obscured.

Several issues such as work delay, lack of communication and integration, lack of knowledge and increase in cost, which are synonymous to the traditional procurement method appear to outweigh the benefit of IBS. Hence, this research aims to suggest an alternative to the traditional procurement method with regard to IBS project implementation. Two objectives were outlined: (1) to identify issues faced by client on current procurement method in IBS project; and (2) to identify the client's perspective on innovative procurement method most suited for IBS project.

This ensuing research reported in this paper is organised in four parts. The first part provide an introduction to IBS with issues concerning its implemenation are emphasised. The second part then explained on the innovative procurement methods before the research methodology is explained. Next, the results from the data analysis are explained, followed by the discussions of the findings.

2. Issues concerning the traditional procurement method and IBS project implementation

According to Anuar et al. (2011), IBS is a mass-production of industrialised systems, using the innovative process of building construction with components produced in a controlled environment. Among the most outstanding IBS projects are Sekisui Home (Japan), Open House (Sweden), Wenswonen (Netherlands) and Living Solution (United Kingdom) (Rahim & Qureshi 2018).

IBS offers greater benefits over the traditional construction method. It applies less formwork on site (Rahim & Qureshi 2018; Anuar et al. 2011) and reduces waste which consequently reduce pollution to the environment. IBS also reduces the number of labour on site in lieu of IBS component installer. IBS therefore save time because prefabrication works are carried out off site and only requires installation on site. With the implementation of IBS, the project will be completed on time and unnecessary expenditures can be avoided (Din et al. 2012).

The traditional procurement is a method that separates the design responsibility from the construction work of a project. In Malaysia, many IBS project still adopt the traditional procurement strategy. The traditional procurement method of IBS is known as 'over the wall' syndrome (Obwegeser & Müller 2018). This suggests lack of communication among parties which leads to fragmentation.

A typical IBS project starts with the employment of design consultant team which include Architect, Structure Engineer, Quantity Surveyor and Mechanical and Electrical Engineer. Brief is then given where building requirements are pass to the design consultant team. Design team will prepare an outline design, preliminary estimation and feasibility study on the project costs. The detail design drawing and specification of the IBS components will be produced after the approval of client. Tender document for bidding is normally prepared at this stage by the quantity surveyor to facilitate the process.

The adoption of the traditional procurement method for IBS projects is not without any critiques. Researchers have been very critical in this particular aspect as the intended benefits of IBS seemed to be reduced. The review of the literature has managed to unearth issues concerning the application of the traditional procurement method in IBS project implementation which are described as follows:

2.1 Time consuming problem

The traditional procurement method for IBS project is considered time consuming. This is because the manufacturing work of components can only be carried out after the design is completed. Besides, longer time is needed during the design stage as complexity increases with regard to modern buildings (Rahmani et al. 2013). Others include design omission found in the design documents as well as the procedures to prepare and approved drawings. Discrepancies also regularly present between dimensions in different schemes which add up to the time needed to improve the design before component production could eventually take place.

2.2 Poor Integration and Communication

The traditional procurement method for IBS project only allows the IBS pre-casters and contracting firm join in the project after the tender stage (Anuar et al. 2011). They only can accept the task that given by client irrecusably. They also are not familiar with the design team then the communication between each other will be less. Therefore, the client as the leader of the project should realize the importance of the relationship among parties to help in achieving the objective of the project.

2.3 Fragmentation

Fragmentation arise due to the isolation of professionals and lack of cooperation between construction parties (Mohd Fateh & Mohammad 2017). This siloed operation may gives rise to conflict which lend a negative impact to the quality of the design process and design outcome.

2.4 Lack of knowledge

The 'over the wall' syndrome (Mohd Fateh & Mohammad 2017; Ojoko et al. 2018) suggested that parties are only interested to transfer the risk to next parties as work completed. There is no knowledge sharing or learning process between the parties. Therefore, various mistakes occur due to the poor knowledge of IBS parties. For example, the most common problems that happen are an improper assembly of the components that normally involved the beam-to-column and column-to-base connections.

2.5 Issues of cost uncertainty

As Ramanathan et al. (2002) and Odeyinka et al. (2012) had mentioned, cost certainty only present at the earlier stage of the construction process. Although a traditional lump sum tender may give the lowest tender price, it may not result in lowest overall construction cost. There will be surely uncertainty and changes in the market forces, interest and inflation rated affect the IBS design, document and tender because of the traditional method is a long term construction.

2.6 Effect of buildability

Buildability improves building design, help to simplify the construction techniques, encourage more effective communication among construction parties and optimize the approach to construction management.

2.7 Lack of early involvement

Lack of contractor early involvement in the design stage would not give a cost-effective solution for IBS project. Construction clients should realize that the expertise of contractor is useful during the building design work. The expertise of contractor can indirectly bring effects in the design process. For example, it helps to prevent the redesign work and inefficiently built design and also enhancing project schedule (Wondimu et al. 2016).

2.8 Risk liability

Under the traditional procurement, the client will take the more risk in the tender stage while the contractor takes risk in the construction

stage. It can seem that both parties take a risk at different construction stage. This will surely contribute a dispute-riddled environment and each party seeking to attribute liability to the other (Rahmani et al. 2013).

3. Innovative procurement approaches in IBS project

The traditional procurement method adopted for IBS project has caused several issues to construction clients. Therefore, there appears suggestions from researchers to implement the innovative procurement approaches for IBS project. According to (Obwegeser & Müller 2018), innovative management and procurement of IBS have not been fully realized by construction parties. An IBS project is requiring partnership and close relationship with the suppliers and contractors from the early stage of construction work as reported by Alias et al. (2014). This suggests that awareness to innovative procurement approaches in IBS project is important for change to take place. Review of the literature has managed to reveal innovative procurement approaches relevant for IBS project implementation which are discussed as follows:

3.1 Partnering

Partnering is defined as a combination of two or more organizations in a long-term period to achieving specific project objectives by maximizing the effectiveness of each participant's resources (Wondimu et al. 2016). It is helps to improve the long-term performance of the individual organization. This innovative procurement approach envisages for a win -win situation between parties involve in the project.

3.2 Integrated Project Delivery

An integrated project delivery aims to coordinate the construction parties, systems, business structures and practices into a construction process (AIA, 2007). The approach gives clients a single point of contact for both design and construction. Team members are requested to work together at every stage of construction either in a decision-making process or when problems occur during the design and construction stage. Through integrated project delivery, a better quality of IBS project will be completed since all the parties are involved in the same project and work towards achieving the same project goal.

3.3 PPP/PFI

According to Takano (2017), public-private partnering (PPP) is described as a framework of accountability and a promise for value for money project. It aims to deliver infrastructure project at much lower cost. Financing the project through PPP could help to accelerate the project completion and in return, the private sector can get their profit once the project is completed. During construction, the private party will participate in the design, implementing the construction process and obtaining the necessary fund while the public sector is responsible to monitor the project to align with the project's objectives.

PFI is another part that under the PPP procurement approach. The PFI aimed to encourage the involvement of private party in delivering the public project. In Malaysia, PFI approach has been recognised as one of the most cost-effective method to procure a public infrastructure work.

3.4 Separation of Procurement from Main Contract

Based on the report by Shaffii (2017), there is a proposed change in the public procurement approach through CITP. The change involves removing the burden of financial liquidity from the contractor and construction client would then be able to purchase the IBS components directly from the manufacturers and manages the payment themselves. This helps contractor to ease their financial obligation from having to purchase the IBS components themselves while IBS suppliers would receive constant demand for the components.

4. Methodology

For this research, the interview method is selected to collect the data in order to achieve the objectives. The interview is a qualitative research method which exists in depth and detail, does not use predetermined categories of analysis, increases understanding of cases and situations, reduces generalizability and focuses more on researcher as his or her skills and competence are crucial to the research (Neuman 2014). Therefore, the respondents for this research are construction clients with prior knowledge and experience in managing IBS project.

This research has employed purposive sampling to identify the respondents for the interviews. Purposive sampling can be defined as 'judgement sampling' which place a value to specific experiences, behaviour and roles of respondents (Uribe & Manzur 2012). Respondents for this research area construction clients who have experienced IBS project before. This follows as they are the main party involves in the project and known to influence the procurement approach for a project.

Besides, this research had also applied the snowball sampling technique. Snowball sampling is a method that research respondent recruits other respondents to answer a research question (Bryman 2013). This method had been used because the population of the developer who implements IBS is "hidden" and "less". Though, the possibility of the respondent to involve in the research could not be guaranteed, the technique is able to increase the number of respondents to a saturation point where derivation of findings could be proposed.

5. Results and discussion

5.1 Demographic information

Five semi-structured interviews have been carried out. Table 1 shows the background of the respondents who have participated in the research. The respondents have been selected following their experience in handling IBS projects.

Despite the limited number of respondents interviewed, the experience that the respondents held in managing IBS projects are valued the most. In this instance, they have been able to provide an in-depth explanation on the issues they have experienced with the traditional procurement method while managing IBS projects. The experience that they held had also provide important points on the most suited procurement approach for managing IBS projects.

Table 1 *Demographic information*

Respondent	Designation	Experience (Year)
A	Senior Manager	10
B	Project Manager	12
C	Senior Site Engineer	10
D	Quantity Surveyor	9
E	Deputy Manager	7
F	Civil Engineer	8

5.2 Insights on issues experienced by the respondents on the traditional procurement method for IBS projects

Table 2 shows the issues the respondents experienced with regard to the traditional procurement method for IBS project. Respondents agreed that completion period (time-consuming problem) tended to be far-stretching than the anticipated period. Besides, poor integration, communication problem and lack of knowledge were the issue that happened frequently during the project period. Issue concerning lack

Table 2 *Issues on the application of the traditional procurement method for IBS projects*

Issues \ Respondents	A	B	C	D	E	F
Time Consuming Problem	√	√	√	√		√
Poor Integration and Communication	√	√	√		√	√
Lack of Knowledge	√		√	√		√
Issues of cost uncertainty				√		
Lack of Early Involvement	√		√			√
Design Issue		√				
Lack of Information			√			
Getting approval from the authorities					√	

of early involvement was pointed out by three respondents while only respondent D claimed that the company had faced cost uncertainty issue. Besides, there were also respondents who have pointed out additional issues that have occurred. In this instance, Respondent B mentioned that the company faced design issue, Respondent C stated that the company faced lack of information while respondent E has experienced the problem of getting approval from the relevant authority.

The results from the interviews suggests that most of the respondents believed that the design stage has been taking a longer time to complete. Based on their explanation, projects will only be converted to IBS design after the selection of contractor. Besides, the respondents also claimed that the design team was taking substantial amount of time to design a suitable IBS design due to the complexity of design in modern buildings. Apart from that, dimension errors which appeared within the same components in the develop schemes had also affect documentation which led towards a much longer period for approval. Respondents agreed that the issues mentioned have produced a 'domino-effect' which affected the whole sequence of works. The sequential nature of the traditional procurement method further exacerbates the already exasperated situation.

Respondents have also weighed in the issue of poor integration and communication in projects. Respondents mentioned a 'trust gap' between consultants and contractors especially when the contractors are only called in in the later stage of the project. With the myriad of parties involved, plus the many contractual relationship that existed, trust require time to develop. In the early stage, parties are frequently unknown to each other and focus has been to complete the individual tasks. As communication in the early stage was less, the tendency to deliver incorrect information was high. This eventually led to conflict which most of the respondents unanimously agreed to avoid.

Respondents also believed that contractors appointed for projects were less knowledgeable with the IBS method of construction. A respondent mentioned that in one of the projects, contractor was found having issue to understand the IBS design. The issue resulted to improper assembly of components, especially the critical connections between the beam-to-column and column-to-base connections. In other seemingly peculiar situation, respondents had also observed limited understanding of IBS among the appointed design team. Respondents reasoned that the siloed working arrangement might had contributed to the situation. The issue highlights the long-standing repercussion of fragmentation among parties in construction industry. It shows that the traditional procurement method imparts the 'over the wall' syndrome which placed constraints for knowledge sharing.

The traditional procurement method only let the contractor to involve at a later stage. Respondents mentioned that time was wasted while waiting for contractors to start with a project. In contrast, if the contractor can involve early in the pre-tender stage, they may be able to give advice to client in preparing a cost-effective solution for IBS project. The expertise of contractor can indirectly bring effects in the design process. For example, it helps to prevent the redesign and improve the scheduling for the project.

The data collection through interviews has managed to unearth issue concerning design. This is an issue which attract attention as the literature seemed to be lacking in this aspect. Some respondents provided an instance where the connections between IBS panels were below par. This despite the IBS panels were produced in a strict concordance to the drawings. The respondents commented that the design issue has appeared due to poor communication and coordination between consultants and contractors. Limitation of time has compounded the issue further where the inability to coordinate design and drawings had caused the production of unsuitable IBS design.

The findings also suggest that information which should accompany the drawings is somewhat lacking. Respondents mentioned that the conversion of the conventional building design to IBS had altered important information causing frequent information lost in the process. A respondent provided a relevant instance where a critical information about the dimension of components were missing. This consequently forced the design team to make assumption which was happened to be wrong. The same mistake also arose in the measurement where re-measurement was required to be carried out. The example given by respondents imply that fragmentation, which is the character of the traditional procurement method often lead to information breakdown. This prove having a detrimental effect to the project.

Another issue considered perplexing involves getting an approval from the authority. In the case of IBS project adopting the traditional procurement method, respondents commented having to go to many different stages in getting the approval. Some respondents mentioned that the authority that they met were unfamiliar with the technologies behind IBS. They were often queried about using pre-fabricated concrete components and steel for constructing houses. The information gathered from the respondents suggests the need for the local authority to be familiar with the IBS technologies so as not to affect the progress of the project.

5.3 Insights on the most suited procurement approach for IBS project

Having mentioned issues connected to the traditional procurement method for IBS project, respondents agreed that partnering is the most suited procurement approach for IBS project. Respondents have weighed the integrated project delivery in second followed by the separation of procurement from the main contract. Regarding PPP and PFI, surprisingly, none of the respondents have agreed to it. Respondents mentioned that PPP and PFI could only be considered should the government is involved in a project.

Partnering is a procurement concept where partners work together to construct IBS project. The approach able to accelerate learning and help to distribute skills and knowledge. Through this, parties with better experience and knowledge tend to bring improvement to the project quality. They also share risk and resources for the success of the project. As there is a greater understanding between partners, any potential mistakes could be reduced thus helping to achieve a win-win situation.

The integrated project delivery approach aims to coordinate all construction parties, systems, business structures and practices into a construction process. Respondents were in the opinion that if this

approach can be implemented in IBS project, a cooperative team will be formed. As previously mentioned, the integrated project delivery approach will create a chance to embed the constructability principles during the design stage of IBS project. This gives chance for parties to share their expertise in preparing an effective design. Hence, it will provide the opportunity for strong pre-construction planning, resolving design-related issues and improving cost control.

Separation of procurement from main contract is an approach that help to remove the contractor's burden of financial liquidity. In this approach, contractor will on be appointed to install the IBS components. Project promoter can directly procure the IBS components from the suppliers and manage the payment themselves. This approach brings benefit to all parties as it reduces the cost to the contractor and increase demand certainty for IBS suppliers. It will also generate competitiveness amongst IBS manufacturers to bid for the contract. Besides, the client can directly negotiate the price with the supplier to prevent any potential mark up of prices via main contractors. There is only one respondent who support the approach indicating unfamiliarity with it.

6. Conclusion and recommendations

Based on the findings, it shows that the industry is still facing issue when adopting IBS through traditional procurement method. Where there is a change of technology or industrialisation in the industry, new and appropriate project procurement is needed. This is to endure it can cater efficiently towards innovative activities. As every project is unique and dynamic in term of processes, risk exposure and responsibilities between all parties therefore the necessity of having a standard form of contract for IBS.

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Application of direct payment clause 30A.0 of the Asian International Arbitration Centre (AIAC) Standard Form of Contract (With Quantities)

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ABSTRACT

Conditional payment such as "pay when paid" or "pay if paid" can create negative chain effect on the parties in construction projects, resulting in delay on the completion of a project, adversarialism and may affect a contractor's reputation. Asian International Arbitration Centre (AIAC) has launched a standard form of contract which is Construction Industry Payment Adjudication Act (CIPAA) compliance with the aim to reduce payment issues. The aim of the research is to identify whether the clause for "direct payment under CIPAA 2012" of the new AIAC standard form of contract can facilitate problems in direct payment. In achieving the aim of the research, five legal cases were analysed and thirty questionnaires forms were distributed. Legal cases analysis findings highlighted that the major reasons of the direct payment issue being referred to court is due to the validity of the direct payment agreement between the disputant's parties. Based on the cases heard before CIPAA enactment, the findings show that out of the three cases, the disputants went to litigation because of the legality of direct payment agreements. Most of the agreements were made orally. For cases analysed after CIPAA was enacted, the findings show that the disputant parties do not opt for adjudication and that the main contractors try to mitigate their responsibilities to the employer. The results from the questionnaires distributed established that, the direct payment clause could be successfully adopted for future use of the industry. Eventhough the AIAC standard form of contract has been formally introduced to the industry, but it is not widely used. From the findings of the questionnaire, it shows that with encouragement and support from the industry, direct payment clause of AIAC standard form of contract have the potential in reducing payment issues in the future. With the remodeling of standard form of contracts that are available in construction industry to be CIPAA compliance, it is hoped that this move may scale down the prevalent payment issues in Malaysian construction industry.

1. Introduction

1.1 Background of study

For decades, the construction industry has been plagued by various constraints encompassing issues such as cost and time overrun, poor quality and lack of sustainability (Bruno et al, 2017). Many factors contribute to the success and failure of a construction project and it has become an interesting arena for research (Yong and Mustaffa, 2017). One of the common area for research is on payment, as it has been the root of every dispute in the construction industry. Sometimes, main contractor feel they have an upper hand and power over the subcontractors. The reason behind this is possibly caused by the tendency of the contractors to ignore their obligations to pay the subcontractors in consideration of their poor financial cash flow condition. Subcontractors are entitled to be informed about their payment especially in recovering them. There are many dispute resolutions in solving this particular problem such as litigation, arbitration and adjudication. On the same wavelength, many institutions such as PAM, PWD and CIDB standard forms of contract have taken great initiatives in avoiding these problems. The introduction of Asian Institute of Arbitration Centre (AIAC) standard form of contract which is CIPAA compliance may help in reducing payment issues.

1.2 Statement of problem

Before CIPAA was enacted, the construction industry has been using PAM and PWD standard form of contract. In PAM standard form of contract, Clause 27.6 provides that the employer may deduct the amount paid to the subcontractor from the amount payable to the contractor. The same provision can also be found in PWD standard form of contract, under Clause 61.2(a). The two clauses in PAM and PWD standard forms of contract require parties in dispute to go through mediation and arbitration proceedings if any dispute pertaining to them cannot be solved. There is a provision in PAM form which gives the option for it to be solved by adjudication. However, there are no specific provisions in PAM and PWD that directly relate the matter to CIPAA. Since the existing standard forms of contract were issued prior to this Act, the Asian International Arbitration Centre (AIAC) or formally known as Kuala Lumpur Regional Arbitration Centre (KLRCA) has taken the initiative to introduce a new standard form of

contract. This form which has been formally launched is to address the prevalent issue of payment in a more explicit manner. These new standard forms of contract are claimed to be more user friendly and CIPAA compliance. This could feasibly be the ultimate solution for direct payment problem. Since the form is relatively new in the industry, the players may be reluctant to use the new form.

1.3 Research objectives

The aim of this research is to identify whether the clause for "direct payment under CIPAA 2012" of the new AIAC standard form of contract can eradicate the problems arising in direct payment. In order to accomplish the aim, these objectives need to be pursued; firstly is to determine the common reason(s) that leads to problems in direct payment from legal perspective and secondly to investigate the awareness of construction industry players of the new direct payment Clause 30A.0 in AIAC standard form of contract (with quantities).

1.4 Significant of study

This research is important in order to help the clients, contractor and subcontractor to know of their rights and obligations arising in the context of direct payment under the new standard form of contract AIAC. In addition, it would shed some light guiding the construction players in solving and protecting their rights to attain healthy cash flow. It is hoped that the findings of the research would encourage the authorities to review their standard form of contracts and include the new provisions that might effectively help in remedying the problems concerning direct payment.

1.5 Scope of study

The main drive of this research is on discovering the perception of the construction industry players on the direct payment provisions with regards to the new standard form of contract released by the AIAC. Court cases have been referred to in identifying the direct payment problems occurred and the solutions to it. This research have been limited to construction cases in Lexis Malaysia under PAM 2006, PWD 2010 and CIPAA 2012, problems on direct payment that occurs among the construction players and perception on the new AIAC standard form of contract towards the direct payment clause.

2. Payment in Construction Project and Related Issues

2.1 Definition of payment

Payment is the amount of money that is going to be paid to the contractor as in the regular interim payments which are progressively paid throughout the duration of the contract (Jane, 2018). Certain procedures enable the parties to calculate the amount, the due date and the final date for payment of any payments falling due under the contract.

2.1.1 Payment clauses in contract documents

In PWD 203A Version 2010, payment clause which is stated in the provision of this contract falls under Clause 28, "payment to contractor and interim certificate". Likewise, in PAM 2006 standard form of contract, the clause falls under Clause 30, "certificates and payment". In both of these standard forms of contract, each of the clauses explain when the employer's representative needs to do valuation and the clauses lay out the procedures of payment that binds the parties to the contract respectively.

2.2 Obligation of paymasters

Payment does not require submission of claim because it is an obligation for the employer to pay the contractor accordingly for the completed works. According to Tony (2018), in the event of valuation of work completed, the regular basis of timely valuation commonly has been stated in advance. The main purpose of the contract is for the contractor to deliver the output (buildings) and for the employer to pay upon completion of work done. It is essential for the paymasters to the subcontractors to know that every rights of their nominated and domestic subcontractor should be paid accordingly for the works that they have done. Generally, all parties' cash flow interest must be protected.

2.3 Payment issues

Payment problems are not new in construction industry. Not only nationally but globally, payment is considered as one of the main issues that have significant influences no matter what industry a person is in. According to European Payment Report (2013), payment is an issue of concern in any industry.

2.3.1 Factors contributing to payment issues

According to Azhari (2014), there are ten factors that contribute to payment issues. The factors are as below

a. Paymaster's Poor Financial Management
b. Paymaster's withholding of payment
c. Conflict among the parties involve
d. The use of pay when paid clause in subcontractor contract
e. Contractual Provisions
f. Disagreement on the valuation of work done
g. Late in certification
h. Duration of project
i. Local Culture or Attitude
j. Technical Problems

2.3.2 Impact of payment issues

There are a lot of impacts that can be caused by payment issues. According to a report by CIDB (2006), the most common effects of non-payment and late payments are the stress created on the contractors, financial hardship and cash flow problems. According to Mohd Khairul (2016), contractors' cash flows are going to be affected due to retention fund, payment term to supplier and subcontractor, advance payment, delay payment and frequency of payment. Sambasivan and Soon (2007) stated that any disruption within the flow of cash will cause monetary hardship and even causing failure lower down the contracting chain. Title of the goods will usually be transferred upon payment and late or non-payment would lead to shortage in material (Sambasivan and Soon, 2007). According to Azhari (2014) the impacts are as below:

a. Creates negative chain effect on other parties
b. Results in delay on completion of project
c. Leads to bankruptcy
d. Project Delay
e. Affect the contractor's reputation
f. Profitability of the project

It can be highlighted that the payment issues that comprise of retention of title, delay in payment, failure of payment, late and non-payment have persisted in the Malaysia construction industry for quite some time now, but have yet to be fully resolved.

2.4 Clauses in standard form of contract for remedies of payment issues

In Clause 27.6 PAM 2006, the Architect may ask the contractor to supply him with reasonable proof of the contractor's claim that he had discharged the previous certificate to the Nominated Subcontractor's payment. If the Contractor fails to do so, the Architect may certify and the Employer may pay such amounts directly to the Nominated Subcontractor and deduct the same amount from the Contractor

Similarly in PWD 2010 form, the normal procedure of payment from client to the contractor falls under Clause 28.3. Regarding the direct payment to the subcontractor, the provision falls under Clause 61.1, which cover the amount that being paid by the Government directly to the Nominated Subcontractor shall be deemed as payment to the Contractor by the Government under the virtue of the contract.

2.5 Direct payment

Emmanuel (2015) stated that problem in late and unfair payment could be influenced by the main contractor and subcontractor's relationships. Based on Supardi (2015), there are three principle methods in paying subcontractors comprising of:

2.5.1 Payment upon certification

Under the payment system, the main contractor receives payment through interim payment certificates and it is a conditional precedent for the main contractor to pay the subcontractors. It is not appropriate for the main contractor to default the payment to the subcontractor after the honoring period of certificate has lapsed.

2.5.2 Direct payment from the employer

Other than the payment upon presentation of the certificate, direct payment is another form of payment in which the payment is being paid directly to the subcontractor by the employer. As far as the employer is concerned, the subcontractor's payment may be apportioned from the Interim or Final Certificate received by the main contractor.

2.5.3 Contingent payment or conditional payment

The last principal method of payment is the contingent payment or also known as under various terms such as "pay if paid" or "pay when pay" and "back to back" provisions in paying the subcontractors. According to May and Siddiqi (2006), the main contractor may transfer the risk of non-payment by the employer to the subcontractor in order to protect their interests. There are a few cases of direct payment that have highlighted contingent payment:

a. *Asiapools (M) Sdn Bhd v IJM Construction Sdn Bhd [2010] 3 MLJ 7*
b. *Seloga Sdn Bhd v UEM Gynisys Sdn Bhd[2007] 7 MLJ 385*
c. *Antah Schindler SdnBhd v SsangyongEngrng&Const. Co Ltd [2008] 3 MLJ 204*

2.6 Direct payment under PAM and PWD

Under PAM 2006, Clause 27.6, where in case that the Contractor does not pay the Subcontractor; the contractor must provide proof within 14 days upon Architect's request. In the event of the Contractor failed to provide such proof, the Architect may certify for the employer (obliged or not to obliged) to pay such amount directly to the Nominated Subcontractor and deduct the amount directly from the Contractor. Similarly under PWD 2010, under Clause 61, after the issuance of Interim Certificate under Clause 28 or Final Certificate under Clause 31, if the contract states the amount to be paid directly to the Nominated Subcontractors or Supplier, the amount shall be deducted from the payment due to the Contractor. It gives security to Government's interest where the contractor will not render the Government in any way liable to Nominated Subcontractor or Supplier (PWD 2010, Clause 62).

2.7 Worldwide perspectives on direct payment

In another part of the globe, the United Kingdom's Housing Grants, Construction and Regeneration Act 1996 finds that the provision of conditional payment is considered unsuccessful with the exception when there is bankruptcy in the contractual chain. According to Sushani (2005), even though these initiatives have been taken, payment problems may still exist. The same occurrence and reports can be seen in the literature in UK (Reilly, 2008), Australia (Barry, 2010) and New Zealand (The Dominion Post, 2008) that pointed to the fact of liquidation could have effect the delayed payment.

2.8 Construction Industry Payment Adjudication Act 2012 (CIPAA 2012)

According to Loshini (2017), Construction Industry Payment and Adjudication Act ("CIPAA 2012") were enacted by the Malaysian Parliament and came into action on 15 April 2014. The introduction of a statutory adjudication process was made with a declared intention to improve payment problems in the construction industry. Small contractors and subcontractors may be facing with cash flow problems and they would be financially weak if they are not paid by employers or in some cases the payment could be unfair or untruthful. In another example, the main contractor could possibly have the upper hand and refuse to pay their subcontractors. The Act identifies this issue and made provisions to address this disputes.

2.9 Adjudication

Adjudication is a form of dispute resolution that was developed back in mid 2000 as an alternative to arbitration in the construction industry. Most of the standard form of contract adapts adjudication as its primary alternative dispute resolution (Dancaster, 2008; Seifert, 2005; Teo, 2008).

Under CIPAA 2012, the clause for direct payment is provided under Section 30A. Even though in PAM 2006 and PWD 2010 have provisions for adjudications and direct payment, but it does not have specific provisions for direct payment clause that refers to CIPAA. For example, in PAM (Rev. 2006), Adjudication and Arbitration are put under the same Clause 34. There is no mention on adjudication in any of the clauses in PWD 2010, only arbitration was mentioned in the standard form of contract. The same can be seen in CIDB 2000 form. The exclusion of adjudication could be because these two forms have been in used before CIPAA 2012 takes its operative effect. However, in KLRCA newly launched form, specific provisions in CIPAA 2012 were mentioned. The provisions for extension of time (clause 23A), loss and expense (clause 24A) and direct payment (clause 30A) of CIPAA 2012 were included in this form.

All of the procedures under CIPAA may help in solving all the payment disputes between the construction players. Maybe this is the reason why AIAC has made their initiative to do a new standard form of contract as one of the solutions.

2.10 Introduction to AIAC

Kuala Lumpur Regional Centre for Arbitration has been established in 1978. Growing strong to 40 years later in 2018, the ideas of Alternative Dispute Resolutions are no longer alien. KLRCA has strived through 40 years with great effort in introducing ADR and educated users with the help of Bar Council and Construction Industry Development Board (CIDB). The initiatives include the amendments to the Arbitration Act 2005 as well as upgrading the role of the KLRCA (Lim, 2009). At present, the Malaysian government has undertaken several reform measures to improve the alternative dispute resolution.

In celebrating the 40th anniversary of KLRCA recently, Datuk Sundra Rajoo has launched a new KLRCA new standard form in accordance with CIPAA compliance and also changed the name of KLRCA to Asian International Arbitration Centre (AIAC) to attract more international parties to arbitrate with them. This move is with clear hope that Malaysia would be acknowledged as the number one arbitration centre worldwide.

2.11 Background of the AIAC standard form of contract

The AIAC standard form of contract is perceived to offers a better way to address the problems and close the gaps by giving solutions that complies with CIPAA. Pursuant to that, AIAC would be expected to ensure that the standard form of contract is up to date and align the updates with the latest laws and construction court judgment in the Malaysian's construction industry. In such cases, it would enable the disputants' parties to easily resolve dispute while the works are still in progress. AIAC is also anticipated to ensure that the new standard form of contract will give benefit to both the employer and contractor and similarly perceived to be a user friendly form. It claims that there are over 60 expressions and words that provide clarity to the contract such as "Clause 33.0 Fossils, Clause 8.30 Weather Conditions and Clause 23.8(c) (viii) Antiquities". There are some key features that are claimed by AIAC (2017) including clarity, integrity, accountability, transparency, continuity and certainty.

To summarise the discussion, the academic community has extensively explored the payment issues and usage adjudication statutory in their research. However, little research has been conducted to show the significance to include the clause of direct payment under the CIPAA 2012 in standard form of construction contract. To address this gap, this research has been designed to investigate the level of perception of the industrial player on the inclusion of the clause of direct payment under CIPAA in the new AIAC standard form of contract and the other standard forms.

3. Methodology

3.1 Introduction

This part of the discussion will primarily be based on research process, tools, data collection and analysis of data. It is based on two modes of research strategies centering around legal research based on analysis of the legal cases and survey conducted on the industry's players to gather information on their views regarding the new AIAC standard form.

3.2 Data collection

This research adopts the descriptive study approach to describe the variables and investigative enquiries of various sorts. The descriptive statistics would furnish the frequencies, the mean and the standard deviation of the set of data. Facts or information that are already available would be analysed further to create a crucial analysis of the content. In this research, legal and quantitative approaches have been used to achieve the objectives.

3.2.1 Legal research

The facts were then filtered through by limiting the selection to cases that are more recent which have been reported from the year of 2010 to 2017. The cases were derived from search conducted through Lexis Malaysia using keywords "direct payment and building contract". The cases were then further filtered into the cases that adopts building contract set out under professional bodies such as Jabatan Kerja Raya (JKR), Pertubuhan Arkitek Malaysia (PAM) and Construction Industry Payment Adjudication Act (CIPAA).

3.2.2 Quantitative research

A set of questionnaire was distributed to achieve the second objective of the current research. The questionnaire responses are then used to investigate the perception of inclusion of the direct payment clause under CIPAA 2012 of AIAC standard form of contract. Questionnaires were sent to all participants throughout Malaysia using the online custom form and were distributed to the industry players. The target sampling is and not limited to thirty targeted respondents.

3.3 Data analysis

The first objective has been concluded through the legal cases analysis. The selected cases have been organized in chronological order, according to the years, from the previous years to most recent. The cases have been studied from the point of view of the facts of cases, judgments passed by the courts and the findings of the cases. The cases have been further scrutinized to investigate their relevancy in the introduction of AIAC standard form of contract. Data that addressed the second objective was analysed using the descriptive analysis. After the data has been obtained through questionnaires, they are then coded, edited and entered into a database.

3.4 Research limitation

There are several limitations of the research. First, the industry chosen is only the construction industry and the respondents are from the related companies in the industry in Malaysia (as this research focuses on the CIPAA 2012 that came into force to govern Malaysia). Thus, the results from this research may not be generalized to other countries which have different political, cultural and economic factors. Second, this research only examines the documents involved in the contract documentation and the focuses directly on documents and records that are related to payment issues or within the application of direct payment clause in CIPAA 2012.

In order to carry out this research, the theoretical and technical assumptions underlying the research methodology in the direct payment concept field were review. In addition, a discussion of the research design for this study was made. On the research strategy, legal case studies have been adopted. This is then further combined with research techniques where the respondents responds were observe through questionnaires and documentation analysis.

4. Data analysis, results and discussion of findings

4.1 Introduction

This part of the paper will be discussing the emerging role of the new AIAC standard form of contract in the context of direct payment as the method in solving payment issues. The legal case analysis will be discussing on the common reasons for direct payment under PAM 2006, PWD 2010 and CIPAA. This is in order to achieve the first objective of the research. The data for the research have been obtained from cases extracted from Lexis Malaysia database. The cases selected were from the year 2010 to 2017. The cases described and analysed have been selected based on the common reasons of direct payment occurrence. The descriptive statistical analysis will discuss on the data collected from the questionnaire distributed to 30 respondents. The interpretations of the said data will be thoroughly discussed accordingly.

4.2 Legal case analysis

It can be observed from the legal cases presented in Table 1 that they

Table 1 *List of Cases*

No	Cases	Reference Number
1	Westform Far East Sdn Bhd v Connaught Heights Sdn Bhd & Ors	(2010) 3 MLJ 459
2	Rira Bina Sdn Bhd v GBC Construction Sdn Bhd	(2011) 2 MLJ 378
3	Desa Samudra Sdn Bhd v Bandar Teknik Sdn Bhd & Ors	(2012) 1 MLJ 729
4	Pembinaan Juta Mekar Sdn Bhd v Sap Holdings Bhd & Ors	(2014) 11 MLJ 821
5	Sigma Elevator (M) Sdn Bhd v Isyoda (M) Sdn Bhd & Anor	(2016) 10 MLJ 635

have several similarities pertaining to direct payment issues. The findings also reveal that there are few limitations to direct payment clause in AIAC standard form of contract. In general, it can be highlighted that the cases were arguing on the existence of contractual agreement of the direct payment. From the cases, direct payment agreement was in existence regardless if it is expressly written or orally agreed. In *Pembinaan Juta Mekar Sdn Bhd v Sap Holdings Bhd & Ors* (2014) 11 MLJ 821, with consistent action of the employer in paying the subcontractor directly for 2 years, court held that there were contractual relationship exists. In addition, even though the agreement was made orally, with enough evidence, subcontractor may exercise their rights to get the payment.

There were some limitations that can be observed from the cases above. Contractor tends to mitigate their responsibility to third party regardless towards the employer or subcontractors. The possible explanation for this is the contractor may not understand the full concept of direct payment. There were possibilities that the contractors are aware of the concept however they try to manipulate and take advantage on the provisions.

4.3 Descriptive statistical analysis

A set of questionnaires were completed by thirty respondents. The data have been collected to investigate the level of awareness among the construction industrial players on the introduction of AIAC standard form of contract. More importantly, data collected are also for the purpose of observing the perspective of the construction players towards the direct payment clause under the AIAC standard form of contract (with quantities).

4.3.1 Awareness on the AIAC standard form of contract

The question asked on whether the respondents were aware of the new AIAC 2018 standard form of contract. Less than a third of the respondents (24%) indicated that they were aware of the existence of AIAC standard form of contract. Unfortunately, despite its objective to resolve the prevalent payment disputes, more than two third of the respondents (23 people) indicated that they were not aware of AIAC standard form of contract.

The result may indicate that the AIAC standard form of contract is yet fully embraced by the construction industry. The initiatives taken by AIAC to organize road shows to promote the standard forms of contract are inadequate to increase the awareness of the forms' presence in the industry. This could possibly be due to lack of communication channel that may not reach out to much smaller players of the industry. Subcontractors are the critical parties that are expected to face higher disadvantages when payment disputes arise. As the data have indicated that there are a lack of awareness in the adoption of AIAC standard form of contract, more promotional activities need to be made in order for the subcontractors to be aware of the existence of the new form.

4.3.2 AIAC 2018 standard form of contract in future project

The following question asked was to assess the potential of the

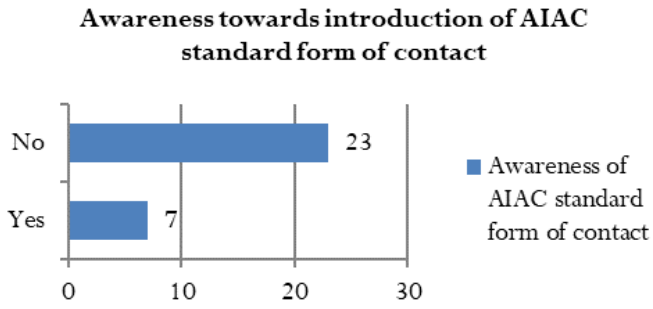

Figure 1*Awareness of AIAC standard form of contract*

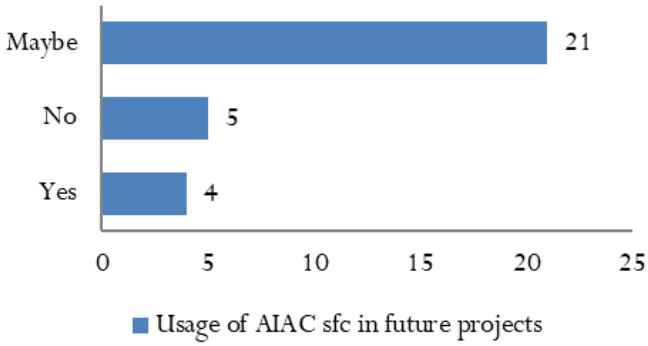

Figure 2 Usage of AIAC standard form in future project.

respondents to use the AIAC standard form of contract in the future. Only four respondents confidently answered positively, while another five respondents indicated that they would not expected to be using the form. Two third responded that they may be using the form in their future projects.

On a positive remark, the positive response promises that the future use of this form looks bright. On the other hand, majority of the responses give different indication to the future use of the form. They are either indecisive because they have not been fully exposed to the form, or that they could be skeptical on the practicality of the form. Another reason contributing to the "uncertain" responses given by the respondents could also be expressed by the smaller numbers of direct payment cases that are resolved with the provisions provided in the form. Similarly, the negative response indicates that the respondents did not have trust in the new form and there are possibilities that they are complacent with the forms that have been established in the industry. Relatively, the reasons behind these responses are further discussed in the analysis under section C of the questionnaire.

4.3.3 Direct Payment (Clause 30A.0) AIAC 2018 standard form of contract can help in reducing "non-payment" or "paid when paid" issues

Following the previous question, the next question was to examine the respondents' agreement on whether the direct payment clause would be able to assist in eliminating or reducing the payment issues. This response would give an indication on the potential success of the direct payment clause on its full implementation. The RII is calculated at an index of 0.77 for this statement. The result reveals that the respondents, though they agree that the direct payment clause can help in reducing the "non-payment" or "paid when paid" issues, there is a possibility of some reservation on their part on its success. This could be due to the fact that the AIAC standard form of contract is still considered new in the industry and has not been used widely.

4.3.4 *Direct payment clause of the standard form contract will change the construction industry payment culture in future*

The subsequent question is to gauge on the respondents' level of agreement on the statement that direct payment may have an effect in changing the payment culture that has been inculcated in the industry. The response that inclines positively towards the statement would give an indication that the direct payment clause would have a chance in setting a new culture of payment in the construction industry. The RII reveals an index of 0.72 which is interpreted as "Agree". This result indicates that the direct payment clause has the potential to change the payment culture in the industry On the contrary, there is a small chance that the change in culture would lead to a bigger problem in the construction industry. One of the possibilities is the mitigation of obligation to pay the subcontractors by the contractors. This potential problem could be due to the fact the direct payment clause is rather vague on the types of payment that are covered under the clause.

4.3.5 *For future improvement of the payment and claim system, all standard form of contract should be CIPAA compliance*

The final question in the questionnaire was targeted to assess the probability that all standard forms of contracts should be improved and be CIPAA compliance. The response would indicate if the AIAC standard form of contract would be successful as a model form that complies with CIPAA and can be benchmarked as payment solution in direct payment issues. From the RII analysis, the index for this question was recorded at 0.79. This shows that most of the respondents agree with the idea of remodeling standard forms of contracts that are available in construction industry to be CIPAA compliance. It is likely that the respondents could identify the importance of CIPAA in solving payment related issue especially for Subcontractors who are directly at the disadvantage of payment issues. All regulatory bodies such as CIDB, PAM and PWD should take the initiative to upgrade their standard form of contracts and adopt CIPAA into their contracts. They should imitate AIAC's move immediately since their current forms are yet to adopt CIPAA. The extra effort in improving the standard form of contract may give a break through to the construction industry players who are reluctant of changes.

On the legal research, out of the five cases, only two cases were heard after CIPAA were enacted. However, both cases do not opt for adjudication as the mode for their payment dispute resolution method. Most of the cases were heard in High Court, a couple of cases went through Court of Appeal and one of the cases went to Federal Court. It is time consuming and costly process to go have a case being heard at the court. Instead of a long-awaited process in litigation, AIAC has made ready the solution to direct payment problems by producing standard form of contract with CIPAA compliance. The standard form synchronously compliments CIPAA's purpose in solving and avoiding short-term cash-flow problems during project delivery. On the contrary, it is also observed that the cases showed certain limitations in the AIAC direct payment clause.

One of the set back is that the direct payment clause does not clearly define the terms of "any payment". The term "any payment" in clause 30A.1 in AIAC could lead to misuse and abuse of the clause. From the responds of the questionnaire distributed, all thirty respondents have given a very good cooperation in assisting this research process. Most of the respondents are also well qualified in terms of their education level and experience in working. Based on the findings, the direct payment Clause 30A.0 in AIAC standard form of contract has a very bright future and gives big impact in the construction industry payment system.

5. Conclusion and recommendations

5.1 Issues pertaining direct payment

Based on the legal case analysis findings, the major reasons of the direct payment issue being referred to court is the validity of the direct payment agreement between the disputant's parties and the fact that other dispute resolutions methods apart from litigation have not been chosen. Without express agreement on direct payment clause, these can jeapordise subcontractors' to express their rights to be paid by the main contractors. In addition, from the findings, the even though some of the cases were held after CIPAA enactment, the disputants does not opt for adjudication as the payment dispute resolution method.

Meanwhile, the research has managed to achieve the objective in investigating the perception on the inclusion of the direct payment clause 30A.0 in AIAC standard form of contract. The research has identified that the clause could be successly adopted for future use of the industry. Even though with the lack of awareness such form existed and the understanding direct payment concept, the AIAC standard form of contract were not fully utilize. Nonetheless, the findings may highlight that there is a reluctant on the part of the industry players to change from what they are comfortable with to something new.

5.2 Possible steps in promoting direct payment clause in AIAC standard form of contract

To enhance and elevate the usage of AIAC standard form of contract, AIAC could have a wider and extensive promotion on the forms. Since AIAC is now recognised internationally, it is only appropriate to spread the exposure internationally. AIAC may also be a bench mark for local standard form of contract to emulate. In addition to that, it is recommended that for the parties concern to have more trainings and conferences to educate them on this latest standard form. From the data obtained, the respondents are from younger generations who are open to challenges and willing to accept changes. This contributes to probable success of the AIAC standard form of contract.

The more educated construction players on the AIAC standard form of contract, the more successful it would be in the future. It is hoped that the findings can be an eye opener for the related construction industry players on the awareness of direct payment in scaling down the prevalent payment issue in the Malaysian construction industry.

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Exploring gamification approach in hazard identification training for Malaysian construction industry

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ABSTRACT

In recent years gaming products have increasingly been used to enhance learning and training development in academic and commercial sectors. Games have become more pervasive; they have been adopted for use in many industries and sectors such as defense, medicine, architecture, education, and city planning and government as tools for workers development. In Malaysia, it has been reported that the construction industry holds the third highest record of occurrences of accidents at work. Therefore, safety training is inevitable to reduce the alarming rate of accidents on construction sites. However, currently, available safety training approaches are still lacking in terms of delivering hands-on training and are more theoretical-instead of being more practical-based. This is due to the nature of the construction environment itself in which safety training involving certain hazards that cannot be implemented hands-on as it may bring harm to trainers, trainees and the environment. Gaming is an approach that applies technology to provide an almost real experience with interactive field training, and also supporting the theory of learning by doing with real case scenario. The purpose of this paper is to seek and explore the differences in existing gamification genres such as simulation game, role-playing, action game, strategy game and etc. Data were collected through available literature. The findings of the study show that serious game is a suitable genre to be adopted as an approach in hazard identification training for the construction industry in Malaysia.

1. Introduction

Construction industry is known as the 4D industries: Dirty, Dangerous, Dark and Death (Bakri et al. 2006). According to the Department of Occupational Safety and Health Malaysia (DOSH), the construction industry in Malaysia has recorded the third highest accident rate after manufacturing and agriculture. Due to this concern, Construction Industrial Development Board (CIDB), National Institute of Occupational Safety and Health (NIOSH) and other related agencies through government initiatives provide trainings to increase awareness and enhance knowledge on safety among key players in the construction industry. Various types of training have been carried out such as induction, on-job training, competency, seminar, and forum (Mohd & Ali 2014; Mansur & Peng 2009). However, the approach taken to deliver these training sessions remain the same for years i.e. lectures, video demonstrations and hands-on. Apart from competency training, other types of training allocate less attention on hands-on approach. Undoubtedly, safety trainings require more hands-on or practical-based approach, but the nature of hazards itself restricts the implementation of practical-based approach in real-life situation.

According to Goetsch (1993) one of the fundamental principles for learning is "learning by doing", emphasizing on adequate hands-on learning opportunities for learners. As a result, some researchers have explored other methods to improve the delivery the safety training especially on the usefulness of technology to create safety training modules (Xie et al. 2006; Ho & Dzeng 2010). By using technology, training has become more flexible in terms of time management, cost and experience (Qin et al. 2016). However, advanced technology such as Virtual Reality (VR) requires some high-end hardware and software which can be costly and limited to researchers who have access to this technology because of the availability of funding for their research (Ebersole 1997). Hence, as highlighted by Filigenzi et al. (2000), there is a need for affordable technology. Affordable technology is a technology that can be developed using a simple software but is able to give the same experience offered by other more advanced and expensive applications such as web-based training, learning via CD-ROM and games (Charsky 2010)

Simulation using gaming approach is more productive and its advantages have been proven in terms of cost and retention of knowledge compared to conventional classroom teaching (Kirriemuir & McFarlane 2004). This is because by actively participating in the learning process, learners take charge of their own learning by observing and "doing". Learners are more likely to retain the knowledge by at least 30% and the percentage may even reach 90% (Goetsch 1993). Gaming is an approach that applies technology to provide a near real experience with interactive field training, and also supporting the theory of learning by doing with real case scenario (Assfalg et al. 2002). For example, in New Zealand transportation department used affordable technology to develop a simulation of driving to measure the awareness and decision making among those new drivers in identifying hazards (Isler & Isler 2011). At the Department of Construction Management, the University of Washington, students were introduced and exposed to a 3D-video game system developed for safety education (Teizer et al. 2013). In Ireland, a simulation game known as MERIT (abbreviated from

Management, Enterprise, Risk, Innovation and Teamwork), originally developed by Loughborough University in the UK, was integrated into the blended learning module to accommodate the needs for Continuing Professional Development (CPD) among construction professionals (Wall & Ahmed 2008). In Malaysia, Virtual Simulated Traffics for Road Safety Education (ViSTREET) has been designed by three researchers from Universiti Malaysia Sarawak for use in teaching and learning of road safety curriculum to schoolchildren aged 12 to 14 (Chuah et al. 2009). However, safety training in construction within the Malaysian context has yet to adopt a game-based VR approach.

2. Why gamification approach?

The definition of the games is interpreted differently by many authors. Wilson et al. (2009) described game by listing their structural components such as dynamic visuals, interaction, rules, and goals while Charsky (2010) described game according to the essentials of the game such as stated task, the player roles, the multiple tasks to the goal, and the degree of player control. Meanwhile, Hays (2005) defined games as "an artificially constructed, competitive activity with a specific goal, a set of rules and constraints that is located in a specific contact" (p.15).

Electronic games can create a more exciting and better interactive approach in context of delivering complex or boring learning content (Prensky 2005). As noted by Whitton & Moseley (2012), game can also enhance the process of learning in terms of playfulness, practice and engagement. This statement has been supported by Gee (2005) who holds the belief that games are designed in a way that triggers a deep motivation for learning. The vast majority of electronic games provide a highly structured environment with tutorials for players who are new to the game. Such games often break down complex tasks into smaller and more manageable tasks, which cater for the individual pace of each player and give immediate and continuous feedback along the way (Gee, 2005). Moreover, electronic games often require players to formulate the content and evaluate hypotheses, experiment with the outcome, which is a cycle of activities that are closely related to the learning process defined as 'experiential learning' (Perryer et al. 2016).

3. Methodology

A deductive approach is based on an earlier theory or model and therefore it moves from the general to the specific (Wilson et al. 2009). It only can be carried out when the structure of analysis is operationalized on the basis of previous knowledge (Wilson et al. 2009). For this study, the content components that need to be analysed consist of phrases, concepts, theories and the characteristic which fall under objectivity outcome. This outcome only pursues the basic of context, which the results obtained will remain the same from each document or message (Wilson et al. 2009). Pre-determine coding to extract the findings.

Hence, for this study the deductive content analysis study was carried out to distinguish the type of gamification genres. The keywords and the benefit from both generated to analyse the content of the study. Besides that, attributes of the serious game are ascertained through the review from previous studies. However, these attributes need to be incorporated into the nature of construction safety training. Then, it is important to conduct the content analysis as an approach for the researcher to make an observation about the implicit messages that are conveyed. Therefore, the analysis was conducted based on the five steps of deductive content analysis (Figure 1).

The Web of Science and SCOPUS database were used to search the relevant research article articles consist of the report, journals and proceedings from 1994 to 2018. The identified articles were sorted

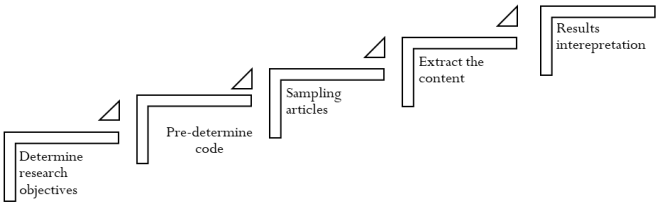

Figure 1 *Step model of deductive category application*

through three phases searching for example types of gamification genre, purpose, training or learning and application in industry. Hence, the after reading, the relevant article is brought together according to the following topic [1] Types of game genre (15 articles), and [2] Types of Serious game (10 articles). Even though, the sampling is small, according to Uribe & Manzur (2012) the sampling size range between 6 to 12 enough to carry out content analysis study.

4. Findings

4.1 Types of game

Gaming approach provides a competitive environment for players to achieve their goal (C Girard et al. 2013). It also emphasizes first, learning what to do, then how to do it. Using gaming approach can allow individuals to discover what they have to do in the game, not what they should do, by experiencing themselves (Kirriemuir & McFarlane 2004). This approach will guide the discovery method of training that empowers individuals to solve the problems that arise in the game, which become a part of the training process. However, to identify gaming approach that is suitable to be adopted as a training tool is quite complicated. Table 1 below shows the types of games genre approaches that are available in the game industry.

Even though there are various types of game genre, in this paper, only related genre which are suitable for training and expected to be adopted in hazard identification training module will be discussed. Based on all attributes on simulation games shown in Table 1, it is viewed that simulation game, adventure game and serious game are suitable to be adopted in hazard identification training module. Simulation games attempt to mimic the environment that presents reality as a method of learning. They can be defined as representations of some real-world environment or imitation of a system and process that also have aspects of reality for the participants (Ranchhod et al. 2014). On the other hand, adventure games can be described as story-based games that usually rely on puzzle-solving to move on along the action in a continuum as players proceed from one level to the next (Michael & Chen 2006).

Meanwhile, serious games have several terms that describe the approach used, for example, game-based learning and or game-based training. This approach has been used and discussed for over four decades. Many authors have their own perceptions to define the meaning of serious games. For instance, Michael & Chen (2006) in his book entitled, "Serious Game" concluded serious games as ones that had an explicit and carefully thought-out educational purpose but not intended to be played primarily for amusement. Girard et al. 2013) defined serious games as "digital games, simulations, virtual environments and mixed reality/ media that provide opportunities to engage in activities through responsive narrative/story, gameplay or encounters to inform, influence, for well-being, and/or experience to convey meaning" (p.210). Based on the definitions given, it shows that the only difference between these gaming approaches lies on their intents and purposes. Thus, in order to distinguish between simulation, adventure game and serious game, a review of related literature was conducted. Evaluation was made based on the purpose and the

Table 1 *Summary of Distinguishing between types of games approaches*

Genres	Attributes				
	Purpose	**Focus**	**Design**	**Essence**	**Example**
Adventures Game (Prensky 2001)	Problem-solving	Command	Large, complex world, interesting character and good story	Story, Puzzles, Interface & Exploration	King's Quest Monkey Island
Action Game (Garris et al. 2002)	To keep player moving and create an adrenaline rush	Quick tactical thinking on fly	First-person game Third person games	Weapon Engine	Tomb Raider Deus Ex
Role-Playing game (Etienne 2003)	To polish skills and get an immersive experience	Character attributes and skills		Story Character Combat	Unreak2: XMP
Strategy Game (Michael & Chen 2006)	To manage limited resources to achieve goal	Balancing		Resources, Teams Weapons, Artificial Intelligence (AI) & Mission	Command & Conquer
Simulations Game (Crookall 2010)	To fulfil layer's fantasy that cannot be done in real life.	Rich experience		Interface	NASCAR Racing 3
Sports Game (ASEP 2013)	To fulfil player's fantasy to become	Emulating an athlete's action	Animation Original rules of the sport	Motion Interface	Sydney 2000
Fight Game (Michael & Chen 2006)	To create quick bursts of swift and intense action	Simple, direct and very engaging	great graphics, Graphic effect Sound effects Easy move	Character Weapon	Mortal Kombat Deception
Casual Game (Michael & Chen 2006)	Easy to learn but not difficult to master	Strategic decision and enhanced level of skills	Simple Uncluttered interface	Rules	Who wants to be a millionaire Hear, Solitaire, Poker
God Game (Michael & Chen 2006)	To push player to choose his own path.	Decision making	Simple interface	Compelling activities Variety of choice	Sim City
Educational Game (Schrader & Bastiaens 2012)	To teach a specific body of knowledge	Transferring knowledge	Simple interface Engage emotion Interactivity	Goal Target group Reward	Reader Rabbit Oregon Trail
Serious Game (Gomes et al. 2013)	To learn by doing and transferring knowledge	Rich experience and on problem-solving		Story, art, software & pedagogy	Military
Puzzles Game (Michael & Chen 2006)	To allow players to challenge himself	Creative thinking	Simple interface	Problems Hints to solution Fun	Heaven & Earth Law & Order
Online Game (Derryberry 2007)	Depend on the type of game	Depend on the type of game	Long-term commitment Character	Internet	Declaring the right of the avatar Counterstrike

elements of each game.

4.2 Element of game and game purpose

As mentioned in the previous section, classification of games in gaming environment can be categorized according to their intents and purposes. Simulation game, adventure game and serious game have been applied in a gaming environment for education and training purposes. Simulation game has the potential to be applied in vocational training. As such, it has been adopted in many industries for CPD and training. It provides the appropriate learning environments that mimic reality and is often designed to engage the learners in situations that would be too costly, difficult or hazardous to be implemented in the real world (Gredler 1996). One of the advantages of simulation is that it can promote strategic thinking by using repetitive learning methods (Bonk & Dennen 2005).

Conversely, for adventure game, its purpose is problem-solving which focuses on giving commands or instructions. This kind of game genre will train player to give commands or instructions to solve arising problems. Commands or instructions can be given in textual or graphical forms and can be communicated from either a first-person, second-person or third-person perspective (Michael & Chen 2006). In general, adventure game is not played in real time, unless it is an action-adventure hybrid game in which a player usually takes as much time as he wants between turns, and nothing happens in the game environment until he enters a command. More modern adventures are points-and click, in which a player indicates what he wants to do by moving the cursor using the mouse around the screen. Players generally expect adventure games to have large, complex world to explore along with interesting characters and a good storyline. This is a mental contest game that follows certain rules and sometimes rules can be broken for amusement, recreation, or winning a stake (Ulicsak & Wright 2010).

Serious games tend to be linear; the issues, problems and situations are always similar. The focus of these games is to train players on planning and decision-making strategies (Yee Leng et al. 2010). They also tend to be more complex because of their nature being more immersive and focused on strategizing. However serious games are more structured and well designed to allow learners to experience and practice their knowledge that are likely impossible to be done in the real world because of safety concerns as well as cost and time constraints (C Girard et al. 2013). As pointed out by Mitchell & Savill-Smith (2004), well designed computer games can enhance a wide range of skills from psychomotor and spatial to analytical and strategic, and gain insights into learning and recollection capabilities, as well as increase visual selective attention.

For simulation, the design criteria must have some focus, specific and systematic steps. It is an immersive and complex approach that allows players to relate and apply their existing real-life knowledge in the simulation. For adventure game, the structure is also complex and heavy design because it wants to entertain, amuse and get the attention from gamers who want to challenge themselves by moving on to the more difficult levels and ultimately win. On the other hand, serious games are designed to give a real experience and hands-on training based on the real situation, so that the players can have a positive impact and further developed their skills.

Serious games are referred to as the type of games when the focus of

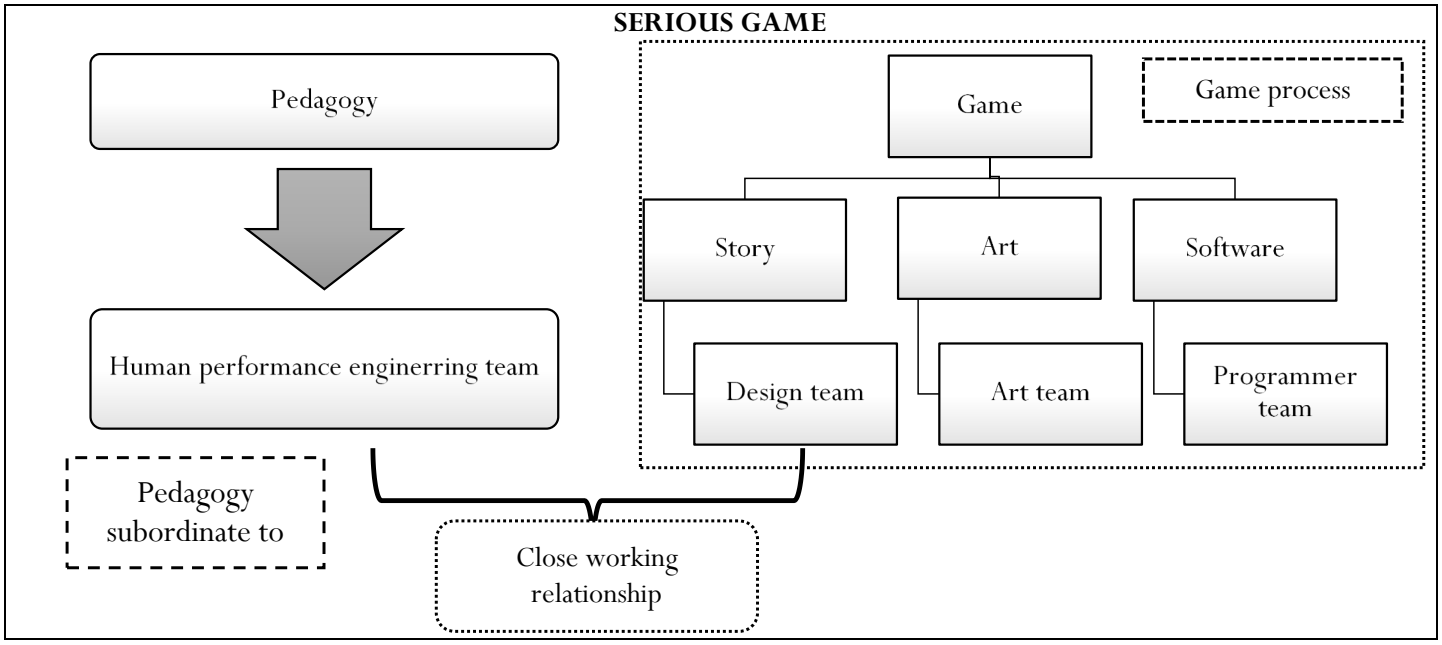

Figure 2 *Concept changes from game to serious game taken from (Zyda 2005)*

such games is for training, advertising, simulation or education. This is because when comparing serious games with other computer or video games, serious games are not only about the story, art and software, but they are beyond that. They have the addition of pedagogy which means that in serious games, there are activities related to education from which players gain knowledge and skills (Zyda 2005). However, pedagogy element must be supported by other elements i.e. art, story and entertainment. Figure 2 shows how serious game works. For the video game to change to a serious game, it needs to include pedagogy to infuse instruction into the gameplay experience.

The above concept has been supported by Martens et al. (2008). They believe that serious games require a game, simulation and learning aspect in almost equal measure. According to them, it is argued that without combining pedagogy or learning goals, the game only becomes a simulation and a game without simulation becomes a simple one with a simple format like an edutainment game (Martens et al., 2008). If gameplay and mechanics are omitted, this will result in a training simulation. Figure 3 shows how the pedagogical elements interplay with computer sciences and games.

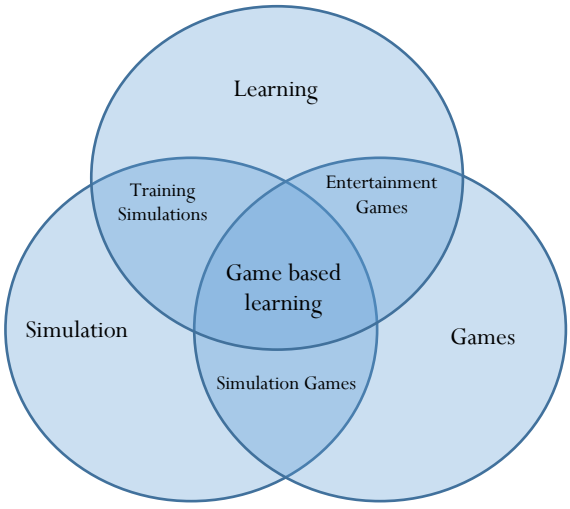

Figure 3 *Interplay of learning, simulation and games (taken from Martens et al., (2008), p.174)*

Table 2 *Summary of distinguishing between the types of game genres*

TYPE OF GAME	CRITERIA		
	Purpose	**Focus**	**Elements**
Simulation game	Training skills	Rich experience	Story, art, software
Education game	Problem-solving	Command	Story, art, software
Serious game	Learning by doing and transferring knowledge	Rich experience and on problem-solving	Story, art, software & pedagogy

Hence, to distinguish between adventure games and serious games, the elements of pedagogy must be added together with three main elements of computer games which are story, art and software (Zyda, 2005). Table 2 shows that the summary of different types of games approaches which were discussed earlier.

As a result of the earlier discussion, it can be concluded that serious games offer various approaches and benefits as a training tool. With the elements of pedagogy, serious games provide the users with an objective that they want to achieve. The relevant objectives that relate to their business or situation will encourage them to achieve the objectives. Besides that, a serious game also presents information as nested problems through the story elements which can be designed according to the needs of the user. This will give the user motivation to complete the objective. In spite of this, the user has to actively get involved in the scenario to work out how to achieve the objective. Serious games can also utilize interesting characters and reward loops to keep user pushing forward, which will lead the user to immersive into the scenario and become emotionally invested in seeing it through.

4.3 Serious game

Serious game "is all about leveraging the power of computer games to captive and engage end-users for a specific purpose, such as to develop new knowledge and skills" (Corti (2006), p.1), which highlights the usefulness of technology in delivering knowledge and skills. Serious games can enrich learning and development in both commercial and academic sectors. Besides that, Backlund & Engstrom (2007) argue that by training using serious games, the learners will have an advantage over a real investigation for example in fire safety training, because learners are able to explore multiple outcomes for particular actions as

Table 3 *Summary of types of serious game (Sawyer & Smith, 2008)*

Types of serious game	Purpose	Example of game
Advergames	To increase recruitment	*Army Game*
Edutainment	Entertainment game to be educational	*Oregon Trail* and *Math Blasters* - teach kids history and math
Game-based Learning	to retain and apply said subject matter to the real world	*Historia* – learning history
Training and Simulation Games	to teach effective behaviour in the context of simulated conditions have or situations	*Microsoft Flight* - Simulator developed as a comprehensive simulation of civil aviation.
News games	to convey some kind of interactive news or editorial content	*Darfur is Dying* - An online game by mtvU That simulates life in a Darfur refugee camp
Persuasive Games	to change attitudes or behaviours of the users through persuasion	*Colorfall* -Created with Humana Games for Health to Promote a healthy life.
Organizational-dynamic	For furthering personal development and character building	*Houthoff Buruma* developed by Dutch law firm Houthoff Buruma.
Games for Health	Educate people regarding health matter	*Funphysio*: This game helps patients in physical therapy treatments.
Edumarket	combine several aspects or goals	*Food Forces*: combines news, persuasive and edutainment goals

opposed to being forced to choose only one 'final' action. This approach has been linked to better learning outcomes (Gee, 2005).

Sawyer & Smith (2008) have identified nine types of serious games, classified according to their purposes: [1] Advergames, [2] Edutainment, [3] Game-based Learning, [4] News games , [5] Training and Simulation Games, [6] Persuasive Games , [7] Organizational- dynamic, [8] Game for Health and [9] Edumarket (educational games that are available in the market). Table 3 shows the summary of types of serious games.

Thus, for the purpose of this research, Edumarket game is proposed to be adopted in developing hazard identification training module. Combination between Advergame, Game-based Learning and Training and Simulation game will fulfil the requirements of the hazard identification training module which are to advertise, attract and transfer knowledge among construction workers.

5. Serious game for hazard identification training

Hazard identification training is a part of the Hazard Identification Risk Assessment and Risk Control (HIRARC) training module in NIOSH module of training (NIOSH 2017). The purposes of this training are 1) to train construction workers in identifying unsafe act and unsafe condition that exist in the working environment; 2) to train their action toward hazard; and, 3) to train decision-making skills in handling hazard wisely. This training should be done visually and hands-on so that the consequences of the decisions made can be seen and will remain accessible. Such consequences will make trainees become more cautious while carrying out their tasks. However, hazard itself is harmful. Therefore, to apply hands-on approach in training is sometimes almost impossible in real life because this will expose the trainees, trainers and the environment to risks. Therefore, serious game approach can be a practical solution.

The attributes of serious game which offer a visual training with a real based scenario allow construction workers to train and apply their knowledge without unnecessary harm. Due to the nature of the construction industry, a simulated training with the real people and hazard simply just for training purpose is very unlikely. This is where serious games can become the missing link between knowledge and hands-on training. Serious games enable users to practice their skills using "trial and error" approach with their own existing knowledge and experience (Hess & Gunter 2013) . By using serious games, users actually can see the consequences of their action and decision without getting harm or injured (Backlund & Engstrom 2007). The environment in serious games is also safe for training workers who will be able to practice their skills in a realistic environment and minimize human errors that construction workers will make in real world (Lin et al. 2011).

The pedagogy elements make learning more effective in training decision-making and problem-solving skills in handling hazard wisely. These elements also will be used as guidelines in designing a serious game to appeal to the users and trigger their minds by following the ways of user nature of learning (Harteveld & Guimarães 2007). In this case, the module will apply the experiential learning theory. By using serious game approach, hazard training becomes more flexible in terms of time, cost and health. Table 4 shows the compatibility between serious game and hazard training.

6. Conclusion

The nature of the construction environment requires a new approach to safety training to identify on-site occupational hazards. Serious games have the capability to achieve specific learning objectives by combining the gameplay, simulation and also learning theory. Serious games also offer a flexible approach that enables hands-on, active learning in a safe environment simulated to mimic a real-life situation at the workplace

Table 4 *Compatibility between the natures of hazard identification training vs. serious game*

Nature of hazard training / Criterion of serious game	Harmful	Need to experience	Hands-on training	Problems solving	Decision making
Visual (Abt 1968)	X	X	X		
Immersive (Susi et al. 2007)		X	X		
Scenario-based (K.-Y. Lin, Son, & Rojas, 2011)		X	X	X	X
Safe environment (K.-Y. Lin, Son, & Rojas, 2011)	X	X	X		
Re-usable/ Re-play (Backlund & Engstrom, 2007)		X	X		
Pedagogy (Harteveld & Guimarães 2007)				X	X
Decision making (Hulst & Ruijsendaal, 2012)				X	X

which is also cost-effectiveness for training purposes. It is anticipated that the development of such a blended training module will be of great significance to safety training among construction workers in handling occupational hazards. This is because by developing serious games to be used as a tool for training, these workers can be trained to make wise decisions in handling hazards in a virtual environment that is close to reality at the workplace. More importantly, this approach is not only safe and affordable but also very interactive and entertaining, which can be made available anytime and anywhere.

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