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RESEARCH ARTICLE (PEER-REVIEWED)

Dynamic Representation of Barriers for Adopting Building Information Modelling in Malaysian Tertiary Education

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Abstract

Building Information Modelling (BIM) is deemed to shape the future of the construction sector across the world. At present, the lack of BIM in tertiary education has been the rising concern around the world as the demand for BIM talent increases. The current landscape suggests that few pedagogic researches have been undertaken to advance BIM education, particularly in Malaysia. BIM implementation could only be possible by identifying the potential barriers, which is a basic pre-requisite for successful adoption of BIM. Unfortunately, previous studies on the barriers of BIM adoption have often based on theoretical constructs, which are deterministic in nature. The methodology used could not portray a conclusive correlation of causal relations among the variables, creating difficulty in developing holistic and workable solutions. Therefore, this study aims to develop a methodology that provides a dynamic representation of the barriers in implementing BIM in tertiary education. The methodology combines both the deterministic (feedback from questionnaire survey) and dynamic approach (causal loop diagram). Data was first collected and analysed through a

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questionnaire survey administered among lecturers from selected Malaysian universities. Following that, a dynamic systems approach (causal loop diagram) was used to demonstrate the complex nature and interrelationship of the barriers for a more holistic representation. Results from the deterministic analysis has suggested barriers that relate to technology, while findings from the dynamics has identified the people aspect as the core barrier for BIM adoption. This study has contributed in establishing a methodology that integrates the dynamic approach with the deterministic data towards providing a more holistic representation of a system that further enables the identification of holistic solutions that would address the core barriers inhibiting the implementation of BIM education, particularly at Malaysian Universities.

Keywords

Building Information Modelling (BIM); Tertiary Education; Civil Engineering; Causal Loop Diagram (CLD); Barriers; Malaysia.

Introduction

Education plays a vital role in Building Information Modelling (BIM) implementation, as reflected in the increased demand for people with BIM skills. Zhang, Schmidt and Li (2016) stated that without BIM talent development, no real progress can be made towards construction's sustainability. Therefore, BIM education is an essential element in driving forward the use of BIM within the industry.BIM education is the joint responsibility of construction related organizations, universities, technical colleges, communities of practice and specialized training entities. At present, the lack of BIM education in tertiary studies has raised concerns around the world as the demand for BIM talent increases (Zhang, Schmidt and Li, 2016). Nonetheless, the current landscape suggests that little pedagogic research has been undertaken to advance BIM education, as compared to BIM adoption in the industry. Bataw (2015) suggested that BIM education could be deficient because implementing new technologies into a curriculum can be a difficult task, especially technology as complex as BIM. In addition, most universities are struggling because there is no common understanding of what skills are needed in the industry nor the content, principles, and methods of education for BIM (Sacks and Pikas, 2013). In their study, Rodríguez-Rodríguez and Dávila-Perez (2016) found that the challenge in introducing BIM in the civil engineering curricula includes the lack of BIM knowledge among faculty members, limited time in completing courses and the lengthy time required to make curriculum changes. In another study, Puolitaival and Forsythe (2016) have identified the challenges of BIM education as the lack of teaching-learning resources, difficulty in finding the balance between theory-practice, technology-process and traditional-modern construction project management methods and staff professional development. In Malaysia, findings from a questionnaire survey by Hedayati, Mohandesa and Preece (2015) highlighted that software related issues have been identified as the major barrier of BIM adoption in the Malaysian education system. Hadzaman, Takim and Nawawi (2015) revealed that the BIM maturity level in Malaysia is still at the awareness stage and support from all parties is crucial in spreading the use of BIM, particularly the academia. Hence, Hedayati, Mohandesa and Preece (2015) have called for more research to be conducted among Malaysian academicians in identifying the barriers in academic institutions, including suggestions to eliminate these obstacles in the education system.

Previous studies have investigated the challenges of BIM education by eliciting the most important issues,but limited studies were found on the identification of root causes and the inter-relationship between the different challenges, which could lead to the recurrence of the barriers of BIM adoption (Mamter, Aziz and Zulkepli, 2017). Most studies have been conducted in deterministic manner using quantitative questionnaire survey or qualitative interviews (Yusuf, Ali and Embi, 2016). The sole reliance on the deterministic approach could constraint the overall understanding of an issue because a phenomenon is viewed only from one perspective. This would result in solutions that might not address the core barrier but instead, only overcomes challenges which are thought to be apparent (Belayutham, González and Yiu, 2016).

Therefore, this study aims to explore the core barriers of BIM adoption in tertiary education through the development of a methodology that provides a dynamic representation of the barriers. This study, as part of a larger scale project, has first chosen civil engineering as the subject of interest. The following objectives have been established to achieve the aim of this study: i) to identify the current barriers of BIM adoption in the civil engineering education in Malaysian tertiary institutions; and ii) to represent the barriers through a dynamic representation in the form of a Causal Loop Diagram (CLD).The contribution of this study is twofold: 1) the development of a methodology to represent both qualitative and quantitative approaches in a complex representation; and 2) a dynamic representation of the barriers in adopting BIM in civil engineering tertiary education.

BIM Education

The current shortage of building design professionals trained in BIM remains a barrier to universal adoption of collaborative working practices in the industry (Macdonald, 2012). Sacks and Pikas (2013) claimed that there are many accredited civil engineering, architectural, architectural engineering, construction engineering, and construction management degree programs in the United States, but very few of the programs offer BIM content. As BIM tools and processes become the uptrend in the construction industry, the demand for skilled BIM professionals increases steadily (Zhang, Schmidt and Li, 2016). Hence, it is the duty of tertiary institutions to properly adapt their curriculum so that their graduates become professionals who are able to perform the required BIM skills (Barison and Santos, 2010), because without proper BIM education, no real progress could be made towards achieving construction excellence. Badrinath, Chang and Hsieh (2016) have conducted a study by searching through publications ranging from year 2010 to the present day using different search engines (e.g., Google Scholar, Scopus), which have resulted in the collection of 70 academic publications related to BIM Education. From those publications, almost half were published in 2015 (30 out of 70), which shows that the importance of BIM Education at tertiary level has only picked-up recently. Miller et al. (2013) found that although BIM is increasingly deployed in the New Zealand (NZ) construction industry, the country is yet to have a National BIM Education framework, with only one tertiary institution offering BIM related module. In the UK, Underwoodet al. (2015) have conducted a study on the current position and associated challenges of BIM education and found that the Higher Education Institutions are generally underperforming, subsequently raises the concern towards the target of getting industry players to achieve at least Level 2 BIM by 2016. Similar scenario is observed in the developing nation, China and in regard to that, Zhang, Schmidt and Li(2016) has urged tertiary institutions to stop defending obsolete programs and to ride along the wave of BIM transformation. In order to do so, challenges facing the academia in implementing BIM education should first be understood. The difficulty to embedded BIM in the education system can be factored to different understandings on the needs of the industry, as well as the content, principles and methods of education (Sacks and Pikas, 2013), with significant diversity found in BIM related curriculum (Hedayati, Mohandesa and Preece, 2015). Nonetheless, growing numbers of studies have been conducted to embedded BIM in the curricular for tertiary institutions, such as Sampaio (2015), who has introduced the BIM concept for Civil Engineering at the Technical University of Lisbon, Portugal. Similarly, in Puerto Rico, Rodríguez-Rodríguez and Dávila-Perez (2016) have developed a BIM framework for the Civil Engineering Department of University of Puerto Rico as a guide to develop BIM curriculum in order to meet industry requirements of professionals with BIM skills. Zhang, Wu and Li (2018) have further incorporated Team-Based Learning pedagogy into BIM education through an undergraduate capstone project, in order to enhance BIM competency among Civil Engineering and Management students in China. Similarly, Jin et al. (2018) have provided an insight into the pedagogical practices in an interdisciplinary building design project that has adopted BIM. Findings from their study suggest that students were equipped with BIM capabilities for future employment, as thepedagogical practices have emphasised the link between the academia and the industry. Hu (2018) has further introducedand encouraged BIM-enabled pedagogy, rather than the traditional drafting-based modelling pedagogy, as a teaching platform for technology courses.

BIM EDUCATION IN MALAYSIA

The current limited adoption of BIM education is also apparent in Malaysia. The differences found in studies related to BIM adoption in the industry, as compared to the education sector is appalling. A simple Scopus search TITLE-ABS-KEY using two different terms, 'BIM+Construction+Industry+Malaysia' and 'BIM+Education+Malaysia' found the former to have 26 returns, while the latter with only 7 returns. Hadzaman, Takim and Nawawi (2015) found that BIM maturity in Malaysia is still at the awareness level and support from all parties, including academia is crucial to spread the use of BIM. Hedayati, Mohandesa and Preece (2015) who have conducted a questionnaire survey among lecturers in Universiti Teknologi Malaysia (UTM) found the biggest challenge to be software related, lack of BIM textbook and resources and limited number of courses that students can take. Most lecturers have recommended for educators to be given proper training so that knowledge could be transferred correctly to the students. On the other hand, Khiyon (2016) has collected data from six tertiary institutions offering QS programme in Malaysia and found that the incorporation of BIM into QS programmes in Malaysia is still at a low level with lack of standardisation. It is apparent that studies conducted on BIM education in Malaysia is still at its infancy.

CHALLENGES IN BIM EDUCATION

As mentioned, universities play a major role in the spread of technological changes, such as BIM and the paradigm shift changes the shape of traditional curriculum, which would require acceptance by the entire faculty (Sampaio, 2015). Previous studies have revealed that various factors could deter the adoption of BIM in education. In descending order, Becerik-Gerber, Gerber and Ku (2011) listed the reasons for BIM to be excluded from the curriculum are: no resource to teach; inadequate resources for curriculum change; no room in current curriculum; not an accreditation criterion and inadequate funding. In a similar tone, Rodríguez-Rodríguez and Dávila-Perez (2016) mentioned the lack of faculty resources with BIM skills, the amount of time required to implement curriculum changes and limited time in courses as the barriers of BIM education. Puolitaival and Forsythe (2016) added that the difficulties of BIM adoption lies in finding the balance between theory and practice, technology and process and traditional and emerging CPM methods, while facilitating staffs' professional development. Amongst that, Shelbourn et al. (2017) has also raised concerns on educators who still view BIM as just another CAD programme, while students are forced to learn certain targeted software in their own time. The summary of challenges is given in Table 1.

Table 1 Summary of barriers for BIM education

Id.	Variables	Literature																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
B1	Reluctance to change curricular structure	X			X	X	X		X		X	X						7
B2	Insufficient space in current curricular	X	X		X		X					X	X			X		7
B3	Too much time to amend curricular structure									X						X		2
B4	Legal issues		X															1
B5	Accreditation standards and professional requirements	X	X				X	X				X						5
B6	Reluctance to invest in new curriculum/ software		X	X		X			X				X					5
B7	Lack financial support to train lecturers					X	X				X		X				X	5
B8	Lack proper tools and method to adapt BIM		X	X														2
B9	Lack qualified staffs to teach BIM		X	X							X						X	4
B10	Inexperienced, unskilled and insufficient lecturers to teach BIM			X			X				X					X		4
B11	Senior lecturers having difficulties to teach BIM				X													1
B12	Issues due to uncertainties of the course outcomes			X					X			X	X					4
B13	Misunderstanding on BIM process implementation	X												X				2

Table 1 continued

Id.	Variables	Literature																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
B14	Limited credit hours due to the requirements to Graduate on Time (GOT)		X	X									X					3
B15	Longer time taken to learn BIM software												X	X	X			3
B16	Shortage of student learning tools		X	X		X							X					4
B17	Limitation of BIM software for students' access		X	X														2
B18	Insufficient hands-on training by universities					X	X				X		X					4
B19	Incompatibility of using BIM with courses in the university	X	X															2
B20	Lack of government/ industry encouragement and initiative to adapt BIM in education	X		X								X						3

Note:
1-Badrinath, Chang and Hsieh(2016); 2-Hedayati, Mohandesa and Preece (2015); 3-Khiyon (2016); 4-Macdonald (2012); 5-Sacks and Pikas (2013); 6-Becerik-Gerber, Gerber and Ku (2011); 7-Abdirad and Dossick (2016); 8-Denzer and Hedges (2008);9-Yusuf, Ali and Embi (2016); 10-Khosrowshahi and Arayici (2012); 11-Panuwatwanich et al. (2013);12-Sabongi and Arch (2009); 13-Kymmell (2008);14-Gordon, Azambuja and Werner (2009); 15-Rodríguez-Rodríguez and Dávila-Perez (2016); and 16-Puolitaival and Forsythe (2016)

THE CONCEPT OF PEOPLE, PROCESS AND TECHNOLOGY

The challenges reported by previous studies have referred to various aspects but did not showcase the interrelationship between the different aspects. This has triggered a study by Enegbuma, Aliagha and Ali (2015), who focused on the relationships between people, process and technology aspects in examining the causal relationshipand its effect on BIM adoption. The study found that the process factor significantly affects BIM adoption. Along the same line, Underwood et al. (2015) have perceived the importance of BIM components towards BIM adoption in descending order, starting from people, information, technology and process. Arayici (2011) has earlier mentioned that BIM adoption and implementation approach is actually as much about people and processes as it is about technology, subsequently providing another perspective in addressing the barriers of BIM adoption, particularly in education. Hence, it is essential that those aspects are being viewed from a dynamic perspective that could demonstrate the interrelationship and root causes of certain barriers, rather than the deterministic form found in most of the previous studies. The theoretical construct is shown in Figure 1.

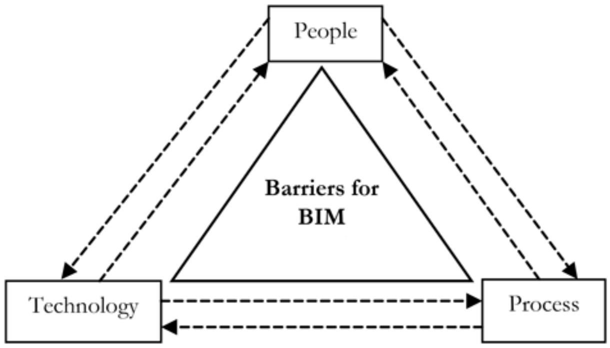

Figure 1 Dynamic interrelationships between people, process and technology aspects of BIM education barriers

The Golden Triangle of People, Process and Technology has commonly been associated as the critical success factor for organizational changes. The phrase People, Process and Technology has been initiated by Harold Leavitt in his paper entitled 'Applied organizational Change in Industry' (Leavitt, 1962). Since then, the model has been used in various attempts to accelerate organizational changes, particularly in the realms of the current paradigm shift towards Industrial Revolution 4.0. For example, Liao and Teo (2018b) have identified and interpreted the critical drivers for change towards BIM implementation based on an organisational change framework, where process-related attributes were found to be the key for full BIM implementation. The different definitions observed in regard to the People, Process and Technology have been summarised in Table 2.

Table 2 Representations of people, process and technology

References	Definition		
	People	Process	Technology
Soja and Soja (2017)	Acceptance; Involvement; Knowledge; Competence; Reluctance or resistance to changes	time overrun; high implementation costs and cost overrun; organisation's competence and support; trainings	System efficiency; system customization; hardware; software; network infrastructure
Liao, Teo and Low (2017)	key stakeholders	work processes; delivery process	Tools
Alshawi (2007)	Staff; skill	Practices	Systems

Table 2 continued

References	Definition		
	People	Process	Technology
Chen, Rukar and Carrillo (2013)	Social and cultural aspects related within an organization; Awareness; understanding; skill requirements of staff within an organization.	A practice, or a series of actions, done for a specific purpose; Part of a system with defined purpose or objective; defined inputs and outputs; key business working rules; procedures	Information and communication technologies (ICT); hardware; software; tools/ applications; technological infrastructure; systems supporting information transaction and sharing.
Dave et al. 2008	Communication; articulation; commitments	Task based approach	ICT systems
Enegbuma, Aliagha and Ali (2014)	Experience; adaptive response; awareness; training	Organizational process; long term goal; managing cost; new methodologies; work flow changes;	BIM software; reference material; component database

Table 3 represents the integration between the barriers (Refer to Table 1) and thethree aspects of people, process and technology (Refer to Table 2).Similar integration has been observed in a study by Liao and Teo (2018a), who have interpreted critical barriers and drivers using organisational change framework, in regard topeople-related factors.Table 3 shows that the process attribute involves most barriers and it is crucial to address the process-based factors effectively as it could inject positive influences into the other aspects (people and technology).

Research Methodology

This study has been divided into two main work phases that addresses the two main objectives, as shown in Table 4. The mixed-method (qualitative and quantitative) approach adopted in this study enhances the reliability and validity of the findings. The quantitative method that have been utilised is questionnaire survey, while the qualitative method includes a forum among lecturers and also the use of literature review. This section describes the methodology adopted in the transformation of the qualitative and quantitative data into a Causal Loop Diagram (CLD) that maps the interrelation and causal relationship between the different barriers of BIM adoption in Malaysian civil engineering education. CLD is a model that portrays the behaviour of variables in a system, presented as causal relationships and feedback loops.

Table 3 Barriers in association with people, process and technology

PEOPLE	PROCESS	TECHNOLOGY
• Reluctance to change curricular structure • Lack qualified staffs to teach BIM • Inexperienced, unskilled and insufficient lecturers to teach BIM • Senior lecturers having difficulties to teach BIM • Longer time taken to learn BIM software	• Insufficient space in current curricular • Too much time to amend curricular structure • Legal issues • Accreditation standards and professional requirements • Reluctance to invest in new curriculum/ software • Lack financial support to train lecturers • Issues due to uncertainties of the course outcomes • Misunderstanding on BIM process implementation • Limited credit hours due to the requirements to Graduate on Time (GOT) • Insufficient hands-on training by universities • Incompatibility of using BIM with courses in the university • Lack of government/ industry encouragement and initiative to adapt BIM in education	• Lack proper tools and method to adapt BIM • Shortage of student learning tools • Limitation of BIM software for students' access

Population and Sampling

For the questionnaire survey, this study has targeted public universities that offer civil engineering courses in the Klang Valley area in Malaysia. The selected area is regarded as the most developed place in the country, with the most numbers of civil engineering faculties in a locality. Public universities were chosen because this type of higher institution generates greater number of graduates as compared to private universities and polytechnics (MOHE, 2015). Hence, the understanding and subsequently addressing barriers among these universities would benefit a larger number of recipients. Non-probability sampling using purposive sampling method has been employed to select the participants for this study. The selected respondents were academicians who were involved or have been part of BIM related committees at their respective organisations, which further justifies their credential and knowledge in recognising the barriers of BIM education. Further details on the sampling frame and sampling is given in Table 5, while Figure 2 provides the teaching profile of the respondents.

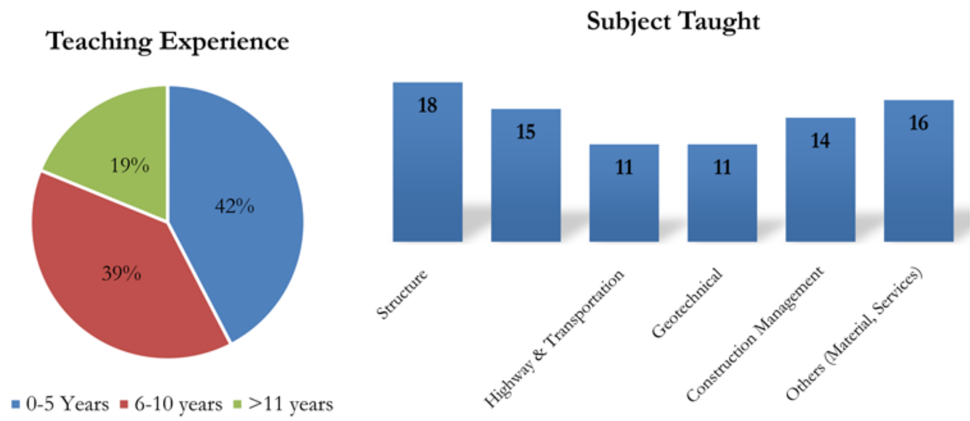

Figure 2 Teaching profile of respondents

As for the forum, a small group of lecturers have been invited to discuss on the matters regarding to BIM education. These lecturers are members of a BIM education committee at Universiti Teknologi MARA, making them a viable respondent due to their knowledge in BIM implementation in the education system. The lecturers came from different backgrounds in civil engineering, such as Structure and Material, Water and Environment, Geotechnical and Transportation and Construction Business and Project Management. Their input has been important, particularly on data verification in Phase 2 (Stage 1 and Stage 2). In Phase 2 (Stage 1), the members were requested to categorise the barriers into either People, Process or Technology aspect based on the definition provided. In Phase 2 (Stage 2), the members were requested to suggest and determine causal relationships between the correlated variables, till consensus.

Table 4 Research Methodology

Stages	Research Methods
Phase 1: The identification of the current barriers in adopting BIM in the civil engineering education in Malaysian tertiary institutions	
Stage 1	Identification of the common barriers in BIM education *Literature Review* • Past studies on the common barriers of adopting BIM in the education system were explored. • 20 barriers were extracted and incorporated into the questionnaire survey. • The literatures used to establish the variables in the questionnaire are given in Table 1.
Stage 2	Collecting responses on the barriers of BIM education in Malaysia *Questionnaire Survey* • Development, pilot study, distribution and data collection. • Data analysis: Reliability test, descriptive analysis, mean and Spearman's Rank Correlation

<table>
<tr><th>Stages</th><th>Research Methods</th></tr>
<tr><td colspan="2">Phase 2: Dynamic interrelation between barriers through the development of Causal Loop Diagram</td></tr>
<tr><td>Stage 1</td><td>People, process and technology categorization
The barriers established in Phase 1 (Stage 1) are further categorized into the Golden Triangle of People, Process and Technology. This is done through several different approaches:
Literature review
• Past literatures in regard to the Golden Triangle are used to establish the definitions forPeople, Process and Technology (Refer to Table 2). Then, relevant barriers associated with the definitions were placed under the similar category (Refer to Table 3).
Forum
• The categorization is further verified among a group of lecturers, who are part of a BIM education committee at a local university.</td></tr>
<tr><td>Stage 2</td><td>Correlation between variables
Spearman's Rank Correlation Data
Based on the quantitative data obtained from the questionnaire survey in Phase 1, the correlation between variables are ascertained through Spearman's Rank Correlation data. Spearman's Rank Correlation could provide a measure of association between the variables by providing monotonic relationship between two variables. The correlation coefficient could be interpreted as follows (Hinkle, Wiersma and Jurs, 2003):
<table>
<tr><th>Correlation Coefficient</th><th>Interpretation</th></tr>
<tr><td>0.00–0.29</td><td>Negligible (N) correlation</td></tr>
<tr><td>0.30–0.49</td><td>Weak (W) correlation</td></tr>
<tr><td>0.50–0.69</td><td>Moderate (M) correlation</td></tr>
<tr><td>0.70–0.89</td><td>Strong (S) correlation</td></tr>
<tr><td>0.90–1.00</td><td>Very strong (VS) correlation</td></tr>
</table>
Causal relationship establishment
Forum and literature review
After establishment of the correlations, all associated variables (only relationships which are Weak to Very Strong) are extracted and defined its causal relationships. The causal relationships are determined through a forum conducted with a group of lecturers. The causal relationships are only finalized after consensus has been reached among the forum members. Further, the causal relationship between the networks are also supported with evidences from literatures. The verified causal relation between the variables are then inputted into the Vensim software, where a dynamic representation in the form of Causal Loop Diagram (CLD) is established.The output would be a CLD representing both the quantitative and qualitative data for this study.</td></tr>
</table>

Table 5 Questionnaire sampling and number of respondents

Universities	Sampling Frame	Sample size (Krejcie and Morgan, 1970)	Respondents	% Response
Universiti Teknologi MARA (UiTM)	178	122	85	69.67
Universiti Malaya (UM)				
Universiti Kebangsaan Malaysia (UKM)				
Universiti Putra Malaysia (UPM)				
Universiti Pertahanan Nasional Malaysia (UPNM)				

The Deterministic Barriers of BIM education in Civil Engineering courses in Malaysia

Following the 69.67% rate of return, with 85 number of respondents, a Reliability Test (Cronbach's Alpha Test) has been carried out to measure the level of tolerance and internal consistency of the data. A value of 0.78 has been obtained. As a rule of thumb (Nunnally, 1978), a value equivalent or larger than 0.7 would signify that the data is consistent and shall be accepted. A mean representation of the barriers for BIM adoption in the civil engineering curriculum is shown in Table 6, listed from the highest to the lowest rank. The deterministic data from the mean value has resulted in 'Limitation of BIM software for students' access at computer laboratories' as the highest ranked and most agreed upon barrier of BIM adoption in the civil engineering curriculum.The lowest value of Standard Deviation (SD) (0.69371) among the top five barriers signifies minimal dispersion from the mean value, indicating that the barrier is much agreed upon by respondents. The barrier is closely related to the 'Technology' factor, followed by the 'lack of proper tools and method to adopt BIM', which is also under the category of Technology. Nonetheless, the top five barriers do have a compilation of barriers from different categories, which is People at the third ranked barrier of 'Longer time taken to learn BIM', followed by Process-based barriers, which are 'Limited credit hours due to the requirements to graduate on time (GOT)' and 'Insufficient space in current curricular structure'.

Table 6 Mean value of barriers for BIM adoption in civil engineering curriculum

Id	Description of Barriers	Mean	SD	Rank	Category
B17	Limitation of BIM software for students' access	3.6824	0.69371	1	Technology
B8	Lack of proper tools and method to adopt BIM	3.6588	0.83883	2	Technology
B15	Longer time taken to learn BIM software	3.6471	0.71889	3	People

Table 6 continued

Id	Description of Barriers	Mean	SD	Rank	Category
B14	Limited credit hours due to the requirements to graduate on time (GOT)	3.5882	0.83515	4	Process
B2	Insufficient space in current curricular structure	3.5412	0.83883	5	Process
B18	Insufficient hands-on training by universities	3.5176	0.62890	6	Process
B10	Inexperienced and unskilled lecturers to teach BIM	3.4471	0.73202	7	People
B9	Lack of qualified staffs to teach BIM	3.4235	0.87799	8	People
B19	Incompatibility of using BIM with courses in the universities	3.4235	0.80735	9	Process
B12	Issues due to uncertainties of the course outcomes	3.4000	0.94112	10	Process
B13	Misunderstanding on BIM process implementation	3.3176	0.84813	11	Process
B3	Too much time to amend the current curricular structure	3.2706	0.73010	12	Process
B16	Shortage of student learning tools	3.2471	0.77006	13	Technology
B20	Lack of government/ industry encouragement and initiatives to adapt BIM in education	3.1882	0.66358	14	Process
B11	Senior lecturers having difficulties to teach BIM	3.1882	0.77910	15	People
B1	Reluctance to change the current curricular structure	3.1765	0.67571	16	People
B7	Lack of financial support to train lecturers	3.1765	0.83347	17	Process
B6	Reluctance to invest in new curriculum/ software	3.1529	0.85225	18	Process
B5	Accreditation standards and professional requirements	3.0118	0.82367	19	Process
B4	Legal issues	2.8235	0.75870	20	Process

The Interrelationship between the Barriers of BIM education in Civil Engineering Courses in Malaysia

A Spearman's Correlation Analysis has been conducted to create a correlational network between the different variables identified in the deterministic approach. Table 7 shows a sample of the results from the Spearman's correlation analysis that was used to describe the strength and direction of relationship between variables. Spearman's is a nonparametric measure of the statistical dependence between two variables. From Table 7, correlational coefficient (r) indicates the strength and direction of the relation between the independent and dependent variables. The relation becomes stronger as the correlation coefficient value approaches -1 or +1. The Sig. (2-tailed), known as *p*-value, indicated by * or ** signifies that any variable larger than 0.05 should be rejected as the data is deemed to be not statistically significant and minimises the chances of relation between the variables. The interrelationship between variables are shown in Table 8, where the correlation coefficient interpretation provided by Hinkle, Wiersma and Jurs (2003) has been used to determine the strength of the relationships. Only relationships which are statistically significant, with strength above weak relation (negligible relations will be excluded) will be considered for further evaluation, to be portrayed graphically in the Causal Loop Diagram (CLD). From the findings, all relations which have the strength from weak and above are found to be statistically significant.

Table 7 Sample analysis of Spearman's correlation

		Barrier 1	Barrier 2	Barrier 3	Barrier 4
Barrier 1	Correlation Coefficient (r)	1.000	0.468**	0.363**	0.028
	Sig. 2-tailed (*p*-value)	Not Applicable	0.000	0.001	0.802
	N	85			

Table 8 Spearman's correlation coefficient interpretation

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
B1		W	W	N	W	W	W	W	W	N	N	N	N	N	N	N	N	N	N	N
B2	W		W	N	N	N	W	N	W	N	N	N	N	N	N	N	N	N	N	W
B3	W	W		N	N	N	N	N	W	N	N	N	N	N	N	N	N	N	N	N
B4	N	N	N		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
B5	W	N	N	N		M	N	N	N	N	N	N	N	W	N	N	N	N	N	N
B6	W	N	N	N	M		N	N	N	N	N	W	N	N	N	N	N	N	W	N
B7	W	W	N	N	N	N		N	N	N	N	N	N	N	N	N	N	N	N	N
B8	W	N	N	N	N	N	N		W	N	N	W	N	N	N	N	W	N	N	N
B9	W	W	W	N	N	N	N	W		N	N	N	N	N	N	N	N	N	N	N
B10	N	N	N	N	N	N	N	N	N		N	W	N	W	N	N	N	N	N	N
B11	N	N	N	N	N	N	N	N	N	N		N	N	N	N	N	N	N	N	N
B12	N	N	N	N	N	W	N	W	N	W	N		N	N	N	N	N	N	N	N
B13	N	N	N	N	N	N	N	N	N	N	N	N		N	N	N	N	N	N	N
B14	N	N	N	N	W	N	N	N	N	W	N	N	N		W	N	N	N	W	N
B15	N	N	N	N	N	N	N	N	N	N	N	N	N	W		N	W	N	W	N
B16	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N		N	N	N	N
B17	N	N	N	N	N	N	N	W	N	N	N	N	N	N	W	N		N	W	N
B18	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N		N	N
B19	N	N	N	N	N	W	N	N	N	N	N	N	N	W	W	N	W	N		N
B20	N	W	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	

Note:

B1-B20	Barriers	Correlation Coefficient	Interpretation
M	Moderate correlation	0.00–0.29	Negligible (N) correlation
W	Weak correlation	0.30–0.49	Weak (W) correlation
N	Negligible correlation	0.50–0.69	Moderate (M) correlation
		0.70–0.89	Strong (S) correlation
		0.90–1.00	Very strong (VS) correlation

Since correlation itself does not imply causation (Schober, Boer and Schwarte, 2018), another evaluation on the cause-effect between those variables have been determined through the qualitative systemic thinking approach. Representation of the causal relation between the variables are reflected through the linkages shown between the factors, as given in Figure 3. The CLD includes the polarities (+/-) between the variables. A '+' polarity would mean that the two variables would move in the same direction (more leads to more, or less leads to less), while a '-'polarity would mean that the two variables would move in a different direction. The polarities (+/-) between those variables (arrows) have been determined and validated through a forum (expert views)among a group of academicians, where the discussion has been conducted till consensus. Additionally, the polarities are verified with the help of previous literatures (For example: the relationship between variable B3→B1 (Too much time to amend the current curricular structure→Reluctance to change the current curricular structure was established based on the statement "in the university, curricular change takes longer time, which serves as an impediment…", taken from Yusuf, Ali and Embi (2016)). A systemic view of the barriers is shown in the CLD, as given in Figure 3.

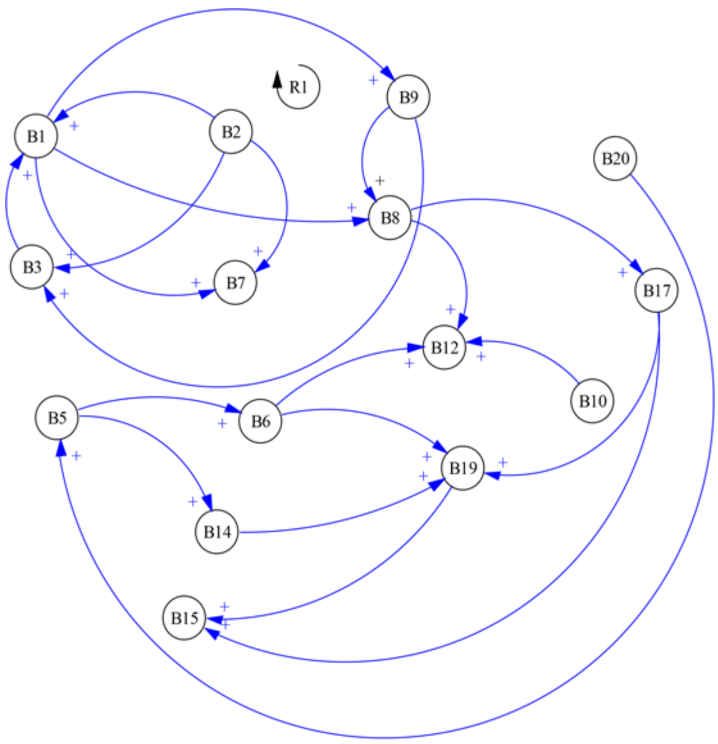

Figure 3A Causal loop diagram

From the CLD, only one Reinforcing Loop (R1) (signifies a closed loop with even number of '+') has been identified, given as follows:

> R1: Barrier 3→1→9→3 (Too much time to amend the current curricular structure→Reluctance to change the current curricular structure→Lack qualified staff to teach BIM→Too much time to amend the current curricular structure)

The Reinforcing Loop (R1) suggests that those factors reinforce each other and has pointed to one core cause, which is 'Too much time to amend the current curricular structure'. Loop R1 could be explained as follows: The increase in the consumption of time to amend current curricular will increase the reluctance of university to change the current curricular. This will subsequently increase the rate for universities not providing and not having qualified lecturers to teach BIM. This in return will increase the time to amend current curricular due to the deficiencies of the staff. Therefore, the cycle will continue unless the core cause of the barrier is addressed. In categorical form, the factors begin with process, followed by the people factor, to people and back to the process factor in return, as shown in Figure 3.

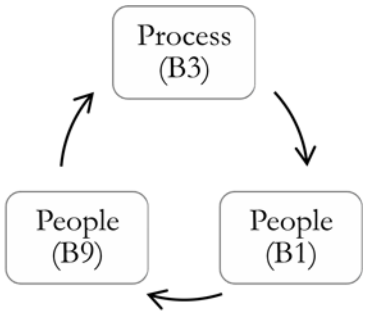

Figure 3B The Interrelation between the Different Aspects of Organisational Changes

Discussion

Two distinct results have been observed between the deterministic and dynamic approach (Refer to Table 9). From the deterministic evaluation (mean value), the respondents generally agreed that 'Limitation of BIM software for students' is the main cause for the lack of BIM adoption within the locality of study. This finding is aligned with the results from Hedayati, Mohandesa and Preece (2015), who found that software related issue is the major barrier of BIM adoption in Malaysian education. However, from the dynamic representation (CLD) that has been developed based on correlation and cause-effect linkages, it is found that 'Too much time to amend the current curricular structure' is the core barrier for the subject under study. The cause-effect relation between the core barrier and other subsequent barriers have also been demonstrated, which enables a systemic perspective that allows solutions that solve the issue at the root level. The identification of the true root cause is important as it will affect solutions that will be taken to overcome the related barrier.

From a deterministic perspective, the common solution would focus on technology, isolating the people and process aspect. Results from the deterministic approach (Refer to Table 6) would drive solutions, which are technology-based, by increasing the allocation of BIM software for student's access at computer laboratories. This might not solve the core issue as the core barrier identified from the dynamic approach is rooted to the process dimension, which is lengthy time consumption to amend the current curricular. As shown in Figure 3, it is suggested that transformation should start from the process factor, without isolating the people factor as both factors are interrelated in a system. This has been mentioned by Enegbuma, Aliagha and Ali (2015), who found that there is a correlation between people, process and technology, and the process factor was found to significantly affect BIM adoption in the industry. In this study, the process factor should be streamlined and simplified so that it does not involve lengthy time frame for changes to be made in the curricular structure. It would further encourage people to amend the curricular in accordance with BIM, subsequently inspiring university to have more staff qualified in BIM and in return, their ability would enable BIM adoption processes to be easier over time. As stated by Arayici et al. (2011), "BIM adoption is actually as much about the people and processes, as it is about the technology".

Table 9 Comparison between the top barriers identified using Deterministic and Dynamic Approach

Approaches	Core Barrier	Mean Rank	People/ Process/ Technology (P/P/T)
Deterministic Approach (Quantitative-Mean)	Limitation of BIM software for student	1	Technology
Dynamic Approach (CLD)	Too much time to amend the current curricular structure	12	Process

Conclusion

This study has highlighted the barriers of BIM adoption in the Malaysian tertiary institution under the civil engineering subject using deterministic and dynamic approaches. The findings suggest two distinct factors that could result in two different solutions to overcome the barriers. However, in reference to the people, process and technology principles, organizational transformation should focus on the process, people then technology, while the dynamic representation has provided the core factor that is process related. The dynamic model that demonstrates the cause and effects enables the understanding of a complex issue by uplifting the root cause, subsequently providing a holistic view of the barriers for the most appropriate solution. Even though the study has been conducted with much meticulousness, certain limitations to the study could not be avoided and shall be enhanced in future. This is in respect to the population and subject of study, which involves civil engineering in particular. As BIM is about integration among various players in the construction industry, future study should expand the current subject matter,to include architectural, quantity survey, mechanical and electrical engineering as well as built environment related subjects. This would subsequently increase the size of the sampling frame, as well as other potential barriers. Academically, this study has contributed in terms of the methodology towards enhancing a purely quantitative-based finding into a dynamic-based result. The methodology could be utilised universally, in other areas that aims to identify core factorsfor a certain issue. In practical, the core barrier identified from this study, which is 'too much time to amend the current curricular structure' would benefit the Malaysian educational institutions in addressing the barriers to BIM adoption, by prioritising the process factor, rather than allocating large sum of money to upgrade hardware and software.

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