International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-2S, July 2019

# Intervention Model of low BIM Adoption in Malaysia: A Need for Learning Institution Precedence

**Shahela Mamter, Abdul Rashid Abdul Aziz, Jafri Zulkepli**

***Abstract*: The government has allocated a substantial budget for the National Key Economic Areas (NKEA) to increase productivity in the construction sector by focusing on increasing technology adoption. However, the Construction Industry Transformation Plan (CITP) has reported that adoption Building Information Modelling (BIM) in Malaysia has estimated 10 per cent which is low in uptake among the construction stake players. In order to encourage BIM adoption in the Malaysia construction industry, the government strategy is to impose level 2 BIM for all government projects from 2019 onwards. Therefore, the research objectives of this paper are to identify the main BIM driving factors and to simulate the intervention model of low BIM adoption in Malaysia. Primary data were collected through a questionnaire survey and analysis of the mean value shows that learning institution scored the highest value as a potential driving factor to holistic BIM adoption. Consequently, using the stock flow diagram in system dynamic modelling, the paper reveals the novelty of the development of the intervention model among the learning institution enablers. The use of the intervention model has the potential to assist the Malaysian government in improving the uptake the CITP and reach for the Fourth Industrial Revolution.**

***Index Terms*: System Dynamic Modelling; BIM adoption; Driving factor; Intervention model.**

## I. INTRODUCTION

Education and learning opportunities as one of the sustainable development goals indicators were presented in 47th Session United Nations Statistical Commission (UNSC). Education goal for sustainable development describes that by 2030 all learners acquire the knowledge and skills needed to promote sustainable development. Consequently, Building Information Modelling (BIM) is key to a viable strategy for fostering sustainable development in Malaysia [1]. BIM knowledge and skills should be a core competency among graduates by promoting holistic collaboration among construction stake players during the construction process. Restructuring the BIM education must be mainstreamed at all levels in education indicator: national education policies, curricula, educator and student assessment.

Since 1999 BIM was adopted in Malaysia [1b], low adoption is still an occurrence issue in the construction industry even though government initiative strategies towards BIM are promising. The value of construction work done in Q2 2018 grew moderately at 5.3 per cent (Q1 2018: 5.9%) to record RM 35.6 billion [2]. A report by [3] indicates low productivity of the construction industry work done is partially caused by limited adoption of new technology and modern construction. By 2020, the government has proactively enforced the construction industry players engaged in government projects worth more than 100 million to achieve a minimum of 40% implementation rate of stage 2 BIM maturity. Research findings [4] show the root causes of low BIM adoption in Malaysia depicted from the causal effect diagram are BIM manager capabilities, BIM learning curve, ratio of BIM modeller and coordinator to training, students' employability rate, quality of graduate students, student industry experiences and university-industry collaboration. These situations are constraining because learning institution and the construction stake players both recognized the significant gap between graduates' knowledge, skill and the human resources expectation from employers in the construction industry.

Accordingly, this paper aims to examine the extent of learning institution precedence towards holistic BIM adoption in Malaysia. The final part recommends the enablers for holistic BIM adoption from learning institutions. It also presents the formulating simulation intervention model has the potential to assist the Malaysian government in improving the BIM uptake in line with the CITP and the Fourth Industrial Revolution.

## II. THE PRECEDENCE OF LEARNING INSTITUTION IN PROMOTING HOLISTIC BIM ADOPTION

The growth and prosperity of a nation depend on their learning institutions because they serve as providers of human capital in technology adoption. A learning institution is an institute or university which specialize in offering skills and knowledge to students. Through education and training play a big role in the BIM adoption process, several scholars have identified the lack of adequately trained personnel as a major occurrence barrier to the BIM adoption [5] [6].

Education institutions have a major role to play in building human capital required by the future generation in supporting the nation's response to sustainable development demand. Hence,

**Revised Manuscript Received on June 10, 2019.**
**Shahela Mamter**, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Seri Iskandar Campus, Perak, Malaysia.
**Abdul Rashid Abdul Aziz**, School of Housing, Building and Planning, Universiti Sains Malaysia.
**Jafri Zulkepli**, School of Quantitative Sciences, Universiti Utara Malaysia.


*Published By:*
*Blue Eyes Intelligence Engineering & Sciences Publication*
*Retrieval Number: B10770782S19/19©BEIESP*

the revolution requires restructuring existing or future courses in the learning institution towards BIM could facilitate the demand. There is a growing and urgent demand learning institution to provide BIM specialized training for students to meet the current needs of the industry. [6] mention the necessity for upskilling of the current workforce but since such standards are rare, there is currently a growing need for educational organisations to host such educational programmes. Simultaneously, the learning institution syllabus contents need to be relevant to the industry practice for the graduates to be employable.

Facing a propitious demand for BIM, many countries of learning institution around the world have started integrating BIM into their program and curricula content through seminars, workshops, conferences, class projects, specific individual courses and training programs. Additionally, this action to prepare the graduates and potential adopters of BIM for the construction industry is in response to the lack of BIM knowledge and skills. In the UK, some universities have incorporated BIM into their course and giving enhancement to existing curricula [7].

Many scholars report that there are barriers to BIM integration into the curriculum of higher education institution [8;9]. The results from survey of 101 US AEC programmes institution conducted by [8b] indicate that the barriers to incorporate of BIM in education included: lack of understanding, inability to use the required tools, lack of time and resources to prepare a new curriculum, lack of room in the curriculum to include new courses to existing curriculum, limited number of courses that can be taken by students within the period they are expected to complete their courses and a lack of appropriate materials and educational resources to teach BIM. Other barriers identified by the researchers include: BIM complexity; lack of interest or willingness to explore new technology by students; lack of support from faculty colleagues and/or administrators; unwillingness to change curriculum to add BIM when BIM itself may be replaced by another technology program in a few years; and uncertainty about which BIM platform.

## III. METHODOLOGY

System Dynamic Modeling will generate own conceptual framework at the initial stage of the study during the problem articulation stage [10;11;12;13;14]. Problem articulation leads to the development of dynamic assumptions using an influence diagram. In other words, an influence diagram represents a dynamic hypothesis for the study. The study methodology was adopted according to [12b] in Figure 1.

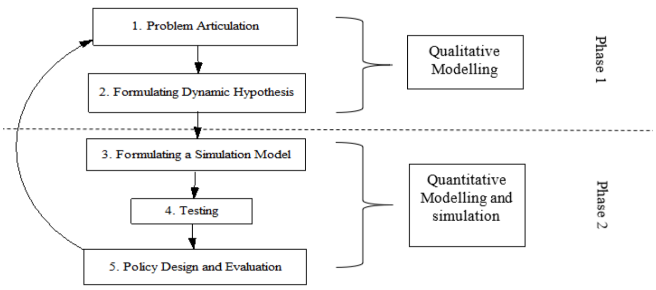


Figure 1: Study methodology using system dynamic modelling according to [12c]

Formulating dynamic hypothesis in phase one of the study begins with interviews are used as a research instrument to the BIM experts. The experts are construction professionals have BIM experiences involving in BIM projects including JKR, CIDB and professional builders in construction organizations. The findings of phase one of the study present the causal loop diagram as a conceptual framework for the driving BIM factors. Therefore, the questionnaire survey identified one of the best methods to validate and generalize the findings of phase one study from the construction industry players. This is supported by [15] who propose the use of a questionnaire in validating the causal framework. Accordingly, this paper presents the findings of phase two of the study. For phase two of the study, the sample population of questionnaire survey was proportionately stratified selected from four main construction stake players in Malaysia.

Table 1: Population of the study

| | Population (N) | Required sample (n) |
|---|---|---|
| Total Groups | 11245 | 415 |
| *Government Agencies* | | |
| *Private clients (Developers)* | | |
| *Consultant organisations* | | |
| *Contractors* | | |

The sampling method was preferred a relative representative for each of the groups that make up the population in the sample.

Table 1 presents the population and sample size respondents' groups involved in the study were from government agencies, private clients (developers), consultant organizations and contractors in Malaysia. Population and recommended sample size for this research study taken mentioned by [16]. A total of 415 questionnaires were administered, of which 125 were returned (approximately 30% response rate). The respondents surveyed represent a spectrum group including 32% government agencies, followed by 16% private clients, 18% consultant organisations and 34% contractors. The data collection was considered successful because it met the 30 per cent response rate benchmark to produce reliable and convincing research result [17].

Hence, for phase two of the



*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

study sought to depict main BIM driving factors and to simulate the stock flow diagram of low BIM adoption in Malaysia. Stock flow diagram was depicted the holistic enablers for BIM adoption from learning institution. To perform a more detailed quantitative analysis, some of the variables listed in the causal loop diagram will be decomposed into more detailed processes, and some of the variables will be changed into several names to make the model clearer. The simulation model was verified and validated to increase confidence in the model. For the policy and practical implication, the research recommends with intervention model in order to give the guideline to enhance the holistic BIM adoption in Malaysia.

## IV. RESULT AND FINDINGS

The presentation of this section follows the order of the objectives of this paper. Phase one of the study depicts the conceptual driving factors of holistic BIM adoption among construction players in Figure 2. Regarding objective one of the papers, to identify the main BIM driving factors. Result and findings; structured interviews have confirmed the factors under three subheading themes: Government intervention, Client procurement approach and Learning/Education institution was identified. The factors that contribute to governments intervention are government enforcement, construction regulation, guideline (BIM guide), financial support (Investment) and government encouragement and continuous promotion. Then, the factors that arise from the client procurement approaches are a contractual agreement, building execution plan (BEP), client information requirement, transparency of the business process, collaboration process and payment schedule. Thus, factors affect against learning/education institution are implementation of BIM course/subject gives earliest readiness and knowledge to potential adopters, professional bodies initiate certification to the competent BIM adopters, government invest in development of reference center, organize conferences in promoting BIM adoption, government supplies research grant for the BIM development and the collaboration between learning/education institution and construction industry encourage the student industry experience rate in BIM.

Figure 2: Conceptual framework of BIM driving factors

Based on the findings, 45.6% of the respondents had 10 years and above experience in the construction industry, but only 4 % of respondents had 6 years and above of BIM experience. This show the BIM adoption is still impeding and not holistically adopted by construction stake players. Table 2 indicates that most of the respondents (72.8%) had BIM experience. 45.6% of the respondents had 1 to 2 years BIM experience, 23.2% of the respondents had 3 to 5 years BIM experience and 4.0% of the respondents had more than 6 years BIM experience. It can be safely assumed that the respondents had adequate experience to supply reliable data for the study. Table 4 further reveals that the respondents claimed confident level knowledge and skill in BIM; 33.6% from respondents claimed not confident, 34.4% from respondents claimed in between and 32% from respondents claimed confidently.

In depth analysis that focuses on 91 respondents of BIM adopters show that 45% of the respondents employed BIM on projects as part of client requested contract deliverables. 39% of the respondents used BIM if there was an existing model already in place to develop and/or interact with while 16% of the respondents organised the third party to manage BIM implementation. The analysis convincingly shows that the Malaysian construction organisation teams still lacked BIM knowledge and skills. Accordingly, it was a root cause of the establishment of the third party (BIM consultant) services to comply with the client needs in BIM. For the future BIM adoption, 45% of the respondents had developed further up the next level. It was proven that the BIM adoption in Malaysia was positively rising even though the adoption was slow. The majority of 38% of the respondents (non-BIM adopter) claimed that they intended to have BIM within 2 to 3 years.

Table 2: Respondent breakdown. (Source: Data analyses)

| Variables | Number of respondents | Percentage (%) |
|---|---|---|
| **Years of construction experience** | (N=125) | |
| Below 5 years | 38 | 30.4 |
| 6 – 9 years | 30 | 24.0 |
| 10 years and above | 57 | 45.6 |
| **Years of BIM experience** | (N=125) | |
| 0 years | 34 | 27.2 |
| 1 – 2 years | 57 | 45.6 |
| 3 – 5 years | 29 | 23.2 |
| 6 years and above | 5 | 4.0 |
| **Confident level knowledge skill in BIM** | (N=125) | |
| Not confident at all | 15 | 12.0 |
| Not quite confident | 27 | 21.6 |
| In between | 43 | 34.4 |
| Quite confident | 30 | 24.0 |
| Very Confident | 10 | 8.0 |
| **Category of BIM adoption** | (N=125) | |
| Adopter | 91 | 73% |
| Non Adopter | 34 | 27 % |
| **Evolution of BIM Adopter** | (N=91) | |
| We employ/use BIM on project as part of our client request as contract deliverables | 41 | 45% |
| We only use BIM if there is an existing model already in place to develop and/or interact with | 35 | 39% |
| We organise third party to manage our BIM implementation | 15 | 16% |
| **Future BIM adoption for BIM adopter** | (N=91) | |
| We remain at current BIM level | 30 | 33% |
| We have developed further for next BIM level | 41 | 45% |
| We reluctant to continue the BIM usage in next project | 20 | 22% |
| **Future BIM adoption for Non-BIM adopter** | (N=34) | |
| We intend to adopt BIM within one year | 3 | 9% |
| We intend to have BIM within 2-3 years | 13 | 38% |
| We intend to have BIM in 4-5 years' time | 8 | 24% |
| Never- we don't think BIM is relevant to our organisation | 10 | 29% |

The next section presents the three themes of BIM driving factors from the interview findings and compare the mean score of the agreements regarding main BIM driving factor. Table 3 shows the result of mean score value analysis of learning institutions factors that lead the BIM driving factors. Therefore, consideration in developing this stock flow diagram model to reflect a framework in giving the guideline to enhance the


Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

holistic BIM adoption among construction players.

Table 3: The rank of potential driving factors to lead holistic BIM adoption

| Potential Driving factors | Total Mean | Standard Deviation | Rank |
|---|---|---|---|
| Learning Institution | 3.81 | 0.74 | 1 |
| Client Procurement Approach | 3.70 | 0.72 | 2 |
| Government Intervention | 3.62 | 0.95 | 3 |

Note: Mean score scale analysis: 1.00 – 1.49 = Not at all, 1.50 – 2.49 = Slightly true, 2.50 – 3.49 = Moderately true, 3.50 – 4.49 = Mostly true, 4.50 – 5.00 = Completely true.

### A. *System Dynamic Model (SDM) Development*

SDM was initially developed by [11b] to reflect the view that the dynamics of industrial systems result from the underlying structure of flows, delays, information, and feedback. According to [18] the elements of a system are modelled to interact through causative feedback loops thereby providing an enhanced understanding of selected dynamic features of current trends and policies which determine the construction sector's development.

The study verifies the usefulness of SDM in the construction industry. SDM was used in this study to capture the interactions and causal relationships of the enablers for holistic BIM adoption from the learning institution. The developed model helped unravel a series of complex problems into more manageable interrelated components. It enables the learning institution organization teams to better understand the potential factors to form BIM adoption at early stage learning and awareness. Accordingly, Vensim PLE (Personal Learning Edition) was used as SDM software which provides a simulation tool applying the basic principles and equations of System Dynamics. However, it provides a more flexible and easier way for a developer to upload the simulations and it was free for educational and personal use.

The availability of numerical information implies that it is not possible to estimate all model parameters. In this study, judgmental and statistical techniques are collectively employed. Confirmation of parameter determines whether the model's parameters are consistent with relevant numerical and descriptive knowledge of the system. As shown inFigure 3, the stock flow diagram depicts the recommendation of the enablers for the holistic BIM adoption from the learning institution.

The parameter values used in this stock flow diagram model were obtained from the head of a programme of one of learning institution (A) in Malaysia. As a constraint, the stock flow diagram model describes only data from one educational institution. The programme was selected because the BIM syllabus was implemented in 2014 and one of the established universities that participated in the BIM roadmap drawn up by CIDB. Table 4 presents all the parameters in the model and their respective values.

The structure of a development model shown in Figure 3 was comprised of three stocks which are tertiary students in architecture, total graduates in architecture and architecture graduates working in the construction sector. The aim here was to demonstrate the potential enablers due to low BIM adoption in Malaysia. The first stock is tertiary students in architecture are increased by the intake rate and depleted by outflow which is the graduate rate. Intake rate is primarily driven by the normal architecture student's intake. Meanwhile, tertiary students in architecture affect the ratio company to the student for industrial placement, ratio students to lecturer and ratio students to software training. The ratio company for industrial placement was driven by total students for industrial placement and is affected by the total company and industrial placement offered. Ratio company also affects the learning curve during industrial placement. Besides, ratio students to the lecturer are driven by the total lecturer and affect the learning curve quality students. Tertiary students in architecture value accumulated the ratio students to software BIM training. Accordingly, several factors are affected by allocated place for software training, maximum students per training, training frequency, government fund and cost per software training. Concurrently, the ratio students to software BIM training affect the software training learning curve. Next, graduate rate accumulated by normal rate value and normal architecture student's intake. The graduate rate accumulated another stock of total graduate in architecture.

The second stock is a total graduate in architecture value is also fed by the value of total employees resigning from their jobs in the construction company. This stock also depleted by outflows which are the ratio of graduate to job opportunities and employability rate. The ratio of graduate to job opportunities is determined by total job opportunities. Thus, employability rate is determined by total job vacancy, normal employee intake in the company, a total graduate in architecture and total ratio learning curve. The last stock is architecture graduates working in the construction sector is depleted by two outflows (the rate of graduates working resign from the construction company and rate of lack of staff in the company) in the model. Historical data for graduates working from 2014 to 2018 was obtained from the records of learning institution alumni and was modified to enable the calibration of the model. The rate of lack of staff was determined by a total needed worker and rate graduates working in the construction sector. The resign rate from construction company was accumulated from normal resign rate, graduates working and resigned rate due to stress.

### B. *Model verification and validation*

Several validation tests were conducted in order to build confidence in the model developed. This includes both behavioural and consistency tests. The tests were conducted under well-established processes. [19] categorise the test categories into two: structural and behaviour validation. However, due to limited availability of historical data, the study only demonstrated some of the testings for model validation. Hence, the tests are a verification test and behaviour test. Verification


Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

test is primarily concerned with parameter verification and dimensional consistency tests [12d]. Each variable must be assigned with a unit to provide a real-life meaning to it. After determining the units of all the variables, the dimensions were checked using the function in the Vensim software. Consequently, the model was validated, as shown in Figure 4. It is worth noting that all the assigned dimensions of the variables are consistent.

Next, the Behaviour test focus on the sensitivity of model behaviour to changes in parameter values [11c] If the simulation output can replicate the actual behaviour of the system under study, be it a historical or a hypothetical pattern, then this is a strong contribution to the overall validity of the model. Besides that, the expert opinion could support the data of behaviour trend [19b]. Several behaviour reproduction tests can be used to evaluate system dynamics models. They are used to determine the closeness of the match between the model behaviour test and the real system. The study employed ‘Employability rate' of architecture student's variables in the model as an example of behaviour test.

Figure 3: Recommendation of the enablers for holistic BIM adoption from learning institution A

Figure 4: Verification and dimensional consistency test

Figure 5 depicts the behaviour test from the study. The simulation behaviour test of the model under the baseline scenario depicting the dynamic behaviour of the model from the base year (2012) to the end of the simulation period (2032) is presented. Reference mode is historical data while current the simulation data. It shows that the difference between simulation and historical data is not much different. Therefore, we can conclude that the model is validated in term of behaviour.

### C. *Policy and Practical Implication*

The World Economy Forum 2018 reports analysis identifies technology, human capital, global trade and networks, and institutional frameworks as key drivers of production for Fourth Industry Revolution [20]. The application of system dynamics methodology can help to predict the long-term outcomes of the current behaviour. This type of method or technique could reduce more time and cost compared to other methods [21]. Hence, some policies should be implemented to predict the behaviour of the model. For policy implication one, the study adopted upskilling existing and producing talent which are one of the key indicators of Fourth Industry Revolution framework. Therefore, the simulation model represents an intervention model of low BIM adoption in Malaysia.

Figure 5: Employability rate of Architecture student’s

For above policy implication, increase the number of companies that provide industrial placement rather than current companies increase the quota for industrial placement. The training given by the industry will boost students' skills and knowledge in BIM. Therefore, we suggest that education institution management discusses with companies to provide more industrial placement. Currently, for the education institution A, only 80 companies are willing to offer industrial placement to the students. As the students increase, we suggest that the industrial placement companies increase to 100. Based on the result as depicted in Figure 6, the total ratio learning curve optimizing increase when the policy one was implemented in the education institution A. Therefore, there is a need to implement the policy to simulate the graduated student knowledge, skills and capabilities in BIM. This could increase the numbers of competence BIM managers in the construction industry thus to increase the BIM adoption in Malaysia.

Figure 6: Simulation Intervention Model for policy implication

## V. CONCLUSION

Precedence of learning or educational institution was considered the main driving factor for adopting holistic BIM in Malaysia. Finally, the prototype intervention simulation model used to facilitate low BIM adoption Malaysia by revealing the pertinent enablers for holistic BIM adoption from the learning institution. The policy implication of this conclusion is that there is a need for upskilling existing employee and simulate the graduated student knowledge, skills and capabilities in BIM. Nevertheless, on the practical implication, the research could lead to leveraging of the collective power of central government clients to drive further efficiencies and improved value for money. It would enable the BIM adopters to focus their energy on the recommended driving factor during implementation so that strategies can be devised to overcome them. The stock flow diagram model has the potential that can be used as a framework and guidelines to assist the Malaysian government in improving the uptake the CITP and reach for the Fourth Industrial Revolution.

## ACKNOWLEDGMENT

The authors would like to thank the Ministry of Higher Education Malaysia (MOHE) for giving the scholarship to the author to accomplish this research.

## APPENDIX

Table 4: Data inputs of variables in the model

| Variables | Unit of Measurement |
|---|---|
| Total university offered Architecture programme | university |
| Normal Architecture students intake | person/university/year |
| Intake rate | person/year |
| Total Lecturers | person |
| Lecturers | Person/university |
| Ratio students to lecturers | dmnl |
| Tertiary Students | person |
| Total company industry placement | company |
| Industrial placement offered | person/company |
| Total students for industrial placement | person |
| Ratio company to student for industrial placement | dmnl |
| Learning curve during Industrial placement | dmnl |
| Graduate rate | person/year |
| Normal rate | 1/year |
| Total graduate in Architecture programme | person |
| Employability rate | person per year |
| Normal hire rate | 1/year |
| Learning curve quality students | dmnl |
| Software training course | software training |
| Total student attended | person/software training/university |
| Total student competent in BIM software | person |
| Ratio student competent in BIM software | dmnl |
| Software training learning curve | dmnl |
| Working in construction sector | person |
| Resign form construction company | person/year |
| Normal resign rate | 1/year |

## REFERENCES


1. M. M. S Mamter, AR Abdul-Aziz, "Stimulating a Sustainable Construction through Holistic BIM Adoption : The Root Causes of Recurring Low BIM Adoption in Malaysia," IOP Conf. Ser. Mater. Sci. Eng. 216, no. September, 2017.
2. www.dosm.gov.my, "QUARTERLY CONSTRUCTION STATISTICS, SECOND QUARTER 2018," 2018.
3. CIDB, "Construction Industry Transformation Programme (CITP) 2016-2020," 2015.
4. S. Mamter, R. Abdul, and J. Zulkepli, "Root Causes Occurrence of Low BIM Adoption in Malaysia : System Dynamics Modelling Approach," AIP Conf. Proceeding, vol. 1903, no. 1, p. 6, 2017.
5. R. Sacks and E. Pikas, "Building Information Modeling Education for Construction Engineering and Management . I : Industry Requirements , State of the Art , and Gap Analysis," vol. 139, no. 11, pp. 1–12, 2013.
6. F. Khosrowshahi and Y. Arayici, "Roadmap for implementation of BIM in the UK construction industry," Eng. Constr. Archit. Manag., vol. 19, no. 6, pp. 610–635, Nov. 2012.
7. W. Wu and R. R. a. Issa, "BIM Education and Recruiting: Survey-Based Comparative Analysis of Issues, Perceptions, and Collaboration Opportunities," J. Prof. Issues Eng. Educ. Pract., vol. 140, no. 2, p. 04013014, Apr. 2014.
8. Burcin Becerik-Gerber, David J. Gerber, and Kihong Ku, "The Pace of Technological Innovation in Architecture, Engineering, and Construction Education: Integrating Recent Trends Into the Curricula," J. Inf. Technol. Constr., vol. 16, pp. 411–432, 2011.
9. Kymmell, W. (2008) Building Information Modeling: Planning and Managing Projects with 4D CAD and Simulations, USA: McGraw Hill Construction
10. G. P. Richardson, "Dominant structure," Syst. Dyn. Rev., vol. 2, no. 1, pp. 68–75, 1986.
11. J. Forrester, "System dynamics, systems thinking, and soft OR," Syst. Dyn. Rev., vol. 10, no. 2, pp. 1–14, 1994.
12. J. D. Sterman, BusinessSystems Thinking and Modeling for a Complex World. McGraw-Hill Higher Education, 2000.
13. R. Cavana and K. Maani, "A Methodological Framework for Integrating Systems Thinking and System Dynamics," Technology, pp. 49–50, 2000.
14. M. Muller, "Research Design and Methods," in Diffusion Dynamics Energy-Efficient Renovations Causalities and Policy Recommendations, Springer, 2013, p. 342.
15. Vennix JAM. 1996. Group Model Building: Facilitating Team Learning Using System Dynamics. Wiley: Chichester
16. R. V Krejcie and D. W. Morgan, "DETERMINING SAMPLE SIZE FOR RESEARCH ACTIVITIES," Educ. Psychol. Meas., vol. 38, pp. 607–610, 1970.
17. Gillham, B. 2000. Case study research methods: Real world research. New York: Continuum.
18. B. Dangerfield, S. Green, and S. Austin, "Understanding construction competitiveness: the contribution of system dynamics," Constr. Innov., vol. 10, no. 4, pp. 408–420, 2010.
19. Sapiri, H., Zulkepli, J., Ahmad, N., Abidin, N. Z., & Hawari, N. N. (2017). Introduction to System Dynamics Modelling and Vensim Software. Universiti Utara Malaysia: UUM Press
20. Ministry of International Trade and Industry, National Policy on Industry 4.0. Ministry of International Trade and Industry, 2018.
21. J. Zulkepli and T. Eldabi, "Technique for improving care integration models," Proc. Eur. Mediterr. Middle East. Conf. Inf. Syst. - Informing Responsible Manag. Sustain. Emerg. Econ. EMCIS 2011, vol. 2011, pp. 46–58, 2011.\


## AUTHORS PROFILE

**Sr Shahela Mamter** is a senior lecturer at Universiti Teknologi MARA, Seri Iskandar Campus. She was registered Quantity Surveyor by Board of Malaysia Quantity Surveyor and Royal Institute Surveyor Malaysia. She is currently as a PhD student at Universiti Sains Malaysia. Her research interests include the root causes of low BIM adoption in Malaysia Construction industry using system dynamic modelling analysis.

**Prof. Abdul Rashid Abdul Aziz** joined Universiti Sains Malaysia in December 1991. Beginning Sept 2019, he will be seconded to Universiti Malaysia Sarawak. He holds a B.Sc Hons. in Quantity Surveying from Reading University, M.Sc. Construction Management from Brunel and Ph.D. from Reading. He has published in more than 100 journal articles, book chapters and books. He has worked for the International Labour Organisation and UN Habitat. His areas of interests are international contracting, foreign labour and construction industry development.

**Ts. Dr. Jafri Zulkepli** is a senior lecturer at Universiti Utara Malaysia. He holds a B.Sc Hons. in Information Technology from Universiti Utara Malaysia, M.Sc. Information Technology (Information Management) from Universiti Teknologi Malaysia and Ph.D Management (Healthcare Simulation) from Brunel University, UK. His area interests are computer modelling and simulation and information technology.