Factors affecting success and difficulty to adopt Building Information Modelling (BIM) among construction firms in Sabah and Sarawak

S S Sinoh\textsuperscript{1}, F Othman\textsuperscript{1} and Z Ibrahim\textsuperscript{1}

\textsuperscript{1}Department of Civil Engineering, University of Malaya, Jalan Universiti, 50603, Kuala Lumpur, Malaysia

Abstract. Building Information Modelling (BIM) is a new yet disruptive technology being promoted among the architecture and engineering sectors especially in Malaysia when it will become mandatory from 2020 onwards. To facilitate the successful adoption of BIM among construction firms, it is necessary to initiate a change in firm culture. This study used a previously created and validated survey instrument to measure factors in firm culture that affected the success and difficulty in BIM adoption among firms in Sabah and Sarawak. Data was collected via email invitation to an online survey instrument sent to 20933 construction firms in East Malaysia with a total response rate of 1.8%. Results show that successful BIM adoption correlate strongly with the encouraging employee innovation, including employees in the decision-making process, software training for employees, having up-to-date software and role of technology in the consultant coordination process. The results also show that medium sized firms have an easier transition to BIM while smaller firms have a more difficult transition to BIM.

1. Introduction

The construction industry in Malaysia accounts for 4.6% of the country’s Gross Domestic Product (GDP) and is expected to grow by 7.3% in 2018 as compared to 6.7% in 2017 [1]. This is an indication of the importance of the construction sector to Malaysia’s growth. Both of the East Malaysian states are among the top six states with the highest contribution to the Nation’s GDP with 9.7% for Sarawak and 6.8% for Sabah. In 2017, relating to growth in the construction sector, Sarawak recorded a 20% growth and Sabah recorded a decline in growth of -1.7% [2]. However, these percentages are predicted to grow in 2018 and beyond as more infrastructure projects are planned for Sabah and Sarawak [3]. Thus, a thorough survey of the construction sector in these states would help contribute to their respective growth and development.

Building Information Modelling (BIM) is an innovation in the construction industry but can also be viewed as a disruptive technology. It is defined as a digital modelling technology with a set of processes to produce, communicate and analyze a shared digital representation throughout a project’s lifecycle [4]. Between 2005 and 2015, more than 90% of all BIM-related articles were published after 2011[5]. This shows how much attention BIM has received in the recent decade. In Malaysia, many papers focusing on BIM in the country have been published. In particular, there have been many studies using mainly semi-structured interviews to measure the perception of BIM among players in the Malaysian construction sector [6-13]. However, there has been a lack of large scale surveys which attempt to sample...
the construction sector population as a whole. Moreover, these surveys do not indicate the state in which they are conducted, nor do they have any indication of firm size.

1.1 BIM adoption in Malaysia

The push to promote BIM implementation across Malaysia has started since 2007 and was supported by the Construction Industry Development Board (CIDB), Construction Research Institute Malaysia (CREAM) and Multimedia Super Corridor (MSC) [8]. Successful examples of BIM application in construction projects in Malaysia include the National Cancer Institute (NCI) Center, Putrajaya and Malaysian Anti-Corruption Commission (MACC) Administration Complex, Shah Alam.

Important applications of BIM in the Malaysian construction industry include quantity takeoff and estimation, clash detection and coordination, integration and collaboration with stakeholders and design and visualization [14][15]. Construction consultants in Malaysia use BIM in 5 ways: Improve product visualization, improve project design, detect design clashes, quantity takeoff and operation and maintenance of building [7].

BIM will be mandatory in Malaysia starting from 2020. However, BIM implementation in Malaysia is still between BIM Level 0 and BIM Level 1 [10]. Adoption of BIM among architectural, quantity surveying and engineering firms were found to be very slow in Malaysia [16][17][18]. Causes of low BIM adoption in Malaysia include absence of national BIM policy, poor holistic readiness, software integration competition strategy and reluctance to share knowledge among companies [10]. The Malaysian construction industry only understands 2 out of 5 concepts relating to BIM which are “BIM as a process” and “BIM as a technology” [6]. Two actions of “Push” from the government and “Pull” from the construction companies are needed for BIM to be implemented in the country successfully [10]. At the company level, to implement BIM successfully, the following must be true: Readiness for change, cultures that support innovation in the company and strong support from top management [10].

Many countries around the world are moving towards the implementation of BIM. However, transitioning to a BIM platform is more than just purchasing new software. In fact, this change represents a shift towards new processes and business models. For a smooth transition to BIM, if any change is initiated at all, requires cultural transformation at the firm level [19]. It is useful to identify cultural attributes which may enable a firm to transition to BIM with the least amount of difficulty. Therefore, the aims of this study are: (1) Identify the present state of BIM adoption in East Malaysia, (2) Examine relationship between perceived firm culture and reported perception of successful adoption and adoption difficulty and (3) Explain the reported aspects of firm culture and how they influence adoption and adoption difficulty.

2. Methods

2.1 Survey Instrument

The study is quantitative survey which uses a survey instrument that was adopted from one used in a doctoral dissertation to measure the factors affecting BIM adoption among architectural firms in Texas, USA which was developed and validated by the same author [20]. The survey instrument consists of 45 items in 5 categories: Demographic information, independent variables, dependent variables, control variables and open-ended answers. The independent variables involved in the study were categorized into 3 scales which are Human Capital (HC), Structure Capital (SC) and Relationship Capital (RC). Responses for the independent and dependent variables consisted of a 5-point Likert Scale: (1) Strongly disagree, (2) Disagree, (3) Neither agree nor disagree, (4) Agree and (5) Strongly agree. Table 1 shows a truncated survey instrument showing the question text for 15 independent variables and 2 dependent variables.

2
Table 1. Truncated survey instrument showing 15 independent variables and 2 dependent variables.

| Item | Question text |
|------|---------------|
| HC01 | The Firm encourages initiatives in developing new solutions or processes. |
| HC02 | The Firm has senior management that exhibits decisive leadership. |
| HC03 | When the Firm initiates an innovation or change all employees are included in the decision process. |
| HC04 | When the Firm initiates a change buy-in by all members, it is quickly achieved. |
| HC05 | The Firm places a high priority on professional development with regards to tools and knowledge. |
| SC01 | Employees of the Firm are provided extensive software training. |
| SC02 | The Firm places a high priority on maintaining up to date technology of both hardware and software. |
| SC03 | The use of software plays a pivotal role in the Firm’s design process. |
| SC04 | Workflows, or the systems by which the work gets finished, are clearly understood by the Firm. |
| SC05 | The Firm makes extensive use of libraries, standards and web resources. |
| RC01 | The Firm actively searches for a better process of communicating design ideas/solutions to clients. |
| RC02 | The Firm actively searches for a better process of exchanging design ideas with team members. |
| RC03 | The Firm actively searches for a better consultant coordination process. |
| RC04 | The use of technology plays a pivotal role in the Firm’s consultant coordination process. |
| RC05 | The use of technology plays a pivotal role in the Firm’s design review process. |
| DV01 | This Firm has successfully transitioned to a Building Information Modelling (BIM) platform. |
| DV02 | The adoption of BIM by the Firm was difficult. |

The website SurveyMonkey was used to create and host the survey instrument which was made available for 2 months from February 2018 to April 2018. A total of 20933 email invitations with a link to the survey instrument were distributed to 14078 construction firms in Sabah and 6855 construction firms in Sarawak. Contact information for all construction firms were obtained from the Construction Industry Development Board (CIDB) online contractor database. These firms ranged from contractor grade G1 to G7.

2.2 Survey Population

The population of the study consisted of all construction companies in the East Malaysian states of Sabah and Sarawak registered as contractors with CIDB. The method for sampling was an online questionnaire that used email invitations with links to the survey. The response rate for this method of sampling was predicted to be very low, thus it was decided that the entire population would be sampled directly to obtain the most amount of responses.

To implement a change in firm culture, it is necessary to look at the firm size since there is a definite relationship between firm size and innovation [21][22][23]. This study uses the number of people employed as a measure of firm size. The study defines a small firm as having 1-6 employees, a medium firm as having 7-15 employees and a large firm as having more than 16 employees. The definition of firm sizes does not match that provided by the CIDB in order to tailor the survey instrument to the population being sampled. Thus, the definitions of firm size must be read within the context of this study.
and not based on external definitions. More importantly, small and medium firms mentioned in this study do not represent Small to Medium Enterprises (SMEs) which are defined differently outside the study.

The data was processed by Statistical Package for Social Sciences (SPSS) software. The Pearson correlation $r$ values were calculated and resulted in values between -1.0 and 1.0. Positive values of the Pearson correlation value show that the value of one variable increases when the value of another variable increases while negative values will result in the opposite effect. Cronbach’s alpha is a measure of internal consistency of a scale or test which results in values that range from 0 to 1. This value is necessary to add validity and accuracy to interpretations on the data. The acceptable range of Cronbach’s alpha to be used in this study will be from 0.70 to 0.95 [24].

3. Results and Discussion

From the 20933 email invitations sent out, a total of 379 responses were received resulting in a 1.8% response rate. Of this, only 128 responses were complete which reduced the total response rate to an actual response rate of 0.6%. The results indicate that most responses are from small to medium firms representing 46% and 32% of total responses respectively. Large firms only represent 22% of total responses. 50% of respondents also report an annual construction value of their projects as being less than RM1 million suggesting that most firms in Sabah and Sarawak are small to medium and take on minor construction projects. Only 10% of firms take on an annual value of projects worth more than RM5 million.

| Independent Variable     | Cronbach’s Alpha | Cronbach’s Alpha Based on Standardized Items | N of Items |
|--------------------------|------------------|---------------------------------------------|------------|
| Human Capital            | 0.713            | 0.716                                       | 5          |
| Structure Capital        | 0.908            | 0.907                                       | 5          |
| Relationship Capital     | 0.868            | 0.867                                       | 5          |

Table 2 shows Cronbach’s alpha scores calculated for all 3 scales of Human Capital, Relationship Capital and Structure Capital were within the acceptable range of 0.70 to 0.95. This shows that the survey instrument used is internally consistent and has a high degree of reliability. Figures 1 to 6 show the calculated Pearson $r$ correlation values for the three different independent variables versus each of the two dependent variables. None of these values exceed 0.6 with only a few dipping into the negative.
3.1 Human capital and successful BIM adoption

Figure 1 shows the calculated Pearson r correlation values of HC versus successful BIM adoption. The r values for HC01 are positive except for medium sized firms, suggesting that they are not as open to encouraging employee innovation. Small sized firms are more trusting to their employees which leads to more successful BIM adoption as compared to large sized firms. The r values for HC02 are highest in small sized firms and decrease as firm size increases. This means that decisive leadership becomes less important as firms get bigger. Decisions made in smaller sized firms have more immediate effects. Another negative correlation can be found in the r value for HC03 of small sized firms which indicates including employees in a decision for small sized firm does not play a key role in BIM adoption success. On the other hand, medium and large sized firms are more open to employee inclusion when initiating a decision. The r values for HC04 increase slightly from small to medium sized firms, but greatly increase for large firms. The highest of all the r values in the study is that for large firms at nearly 0.6. This means that a buy-in by all members is easier to achieve by larger firms. Smaller firms will have a close-knit culture of like-minded staff which would be more difficult to convince [20]. The r values for HC05 show a slight u-shape. Medium sized firms show the lowest r value. Large sized firms have the highest r value followed by small sized firms. This pattern is similar to a u-shape. This suggests that large sized firms place more value in educating employees on the importance of BIM for a successful transition to that platform.

3.2 Human capital and difficulty of BIM adoption

Figure 2 shows the calculated Pearson r correlation values of HC versus difficulty of BIM adoption. Similar to the r value for HC01 on successful BIM adoption, in which the r value for medium sized firms has a negative correlation to difficulty in adoption. The r value of HC01 for medium sized firms encouraging employees to innovate made the transition to BIM easier. Thus, small and large sized firms should seek to better encourage employees to innovate if they want to make the transition to BIM easier. The r values of HC02 were consistent across the firm sizes and indicate that decisive leadership makes the transition to BIM more difficult. The r values of HC03 increase as the firm size increases. A negative r value was reported for small firms, but this increased together with firm size. Thus, small firm sizes include more of their employees in the decision-making process which accounts for a smoother transition to BIM. The r values of HC04 for all firm sizes were more or less consistent with small firm sizes being slightly higher, but still within the values of 0.2 and 0.3. This would indicate that achieving a buy-in by all members makes the transition to BIM more difficult since trying to convince everyone to change would be a challenge. The r values of HC05 for all firm sizes were also the same with a slight decline as firm sizes increase. However, the values do not exceed 0.2 and indicate efforts to promote professional development as making the transition to BIM more difficult.

![Figure 3](image1.png)

**Figure 3.** Pearson r correlation values of Structure Capital (SC) on successful BIM adoption at 4 firm categories.

![Figure 4](image2.png)

**Figure 4.** Pearson r correlation values of Structure Capital (SC) on BIM adoption difficulty at 4 firm categories.
3.3 Structure capital and successful BIM adoption

Figure 3 shows the calculated Pearson r correlation values of SC versus successful BIM adoption. The r values of SC01 for all firm sizes is very high indicating that software training plays a key role in the successful adoption of BIM regardless of firm size. Since BIM is a very software intensive process, it makes sense that employees should be able to use the software naturally and knowledgably. The r values for SC02 decline as firm size increases which may suggest that up to date software and hardware is more important for smaller firms wanting to transition to BIM. The difference between firm sizes is more pronounced than that of SC01. As firm size increases, there is more emphasis on communication among colleagues rather than relying fully on the software in the workflow. A trend similar to that of SC02 is noticed in that the r values for SC03 decrease as firm size increase. This indicates less dependence on software and more on employee interaction and human workflows. The r values for SC04 are highest for large sized firms followed by small and medium. Again, there is a u-shape. This result is consistent with the results shown by SC02 and SC03 that place emphasis on workflows. However, medium firms show a decrease in r value which may suggest medium sized firms are less likely to place importance on workflows as compared to other sized firms. A trend similar to that of SC04 exists for SC05 in that it shows a u-shape. This shows the importance placed on standards, libraries and web resources for small and large sized firms, but not as much for medium firms.

3.4 Structure capital and difficulty of BIM adoption

Figure 4 shows the calculated Pearson r correlation values of SC versus difficulty of BIM adoption. The r values of SC01 for small and large firms are similar. However, that for medium firms is in the negative which would indicate that software training at medium sized firms made the transition to BIM easier. However, small and large firms show that more time provided for software training actually made the transition to BIM more difficult. The r values of SC02 for small and large firms are positive, but that of medium firms is in the negative. This meant that medium sized firms which did not maintain up-to-date technology had a more easier transitioning to BIM. In maintaining up-to-date technology, small firms had a much more difficult time transitioning to BIM compared to large firms. The r values of SC03 increase moving from small firm size to large firm size, but there is virtually no correlation for medium sized firms. This would suggest that the use of software in the design process of medium sized firms has almost no effect on the transition to BIM. While it made the transition to BIM more difficult for small and large firms. The r values of SC04 are consistent across all firm sizes and are between 0.2 and 0.3. This would suggest that poorly understood workflows make the transition to BIM more difficult for all firm sizes. The r values of SC05 for small and medium sized firms are very low, but comparably high for large firms. This indicates large firms rely on standards, libraries and web resources which make the transition to BIM more difficult since these need to be updated or compatible with the incoming BIM software.

![Figure 5. Pearson r correlation values of Relationship Capital (RC) on successful BIM adoption at 4 firm categories.](image)

![Figure 6. Pearson r correlation values of Relationship Capital (RC) on BIM adoption difficulty at 4 firm categories.](image)
3.5 Relationship capital and successful BIM adoption

Figure 5 shows the calculated Pearson r correlation values of RC versus successful BIM adoption. The r values of RC01 show a u-shape with the large firms being larger than the smaller firms. This shows larger and smaller firms place more emphasis on communication with the client as compared to medium firms. Again, medium sized firms show a lower strength of correlation compared to small and large firms. The r values of RC02 for all firm sizes are generally very high and follow a shallow u-shape suggesting that all firms. This shows that the dedication to improving internal processes is an important factor for successful BIM adoption across all firm sizes. The r values of RC03 decrease as firm size increase. Smaller firms place greater importance on consultant coordination. This is consistent with the literature which give the explanation that smaller firms would be more likely to streamline the consultant coordination process since it is very time and resource extensive [20]. Similar to RC03, r values or RC04 decrease as firm size increase. The role of technology is very important for smaller firms. This seems consistent with SC02 and SC03 which show how smaller firms place greater importance on software and hardware when transitioning to a BIM platform. The r values of RC05 for small and medium sized firms are very high compared with a low value for large firms. Again, this is consistent with previous results which show smaller firms more willing to use new technology to improve firm processes.

3.6 Relationship capital and difficulty of BIM adoption

Figure 6 shows the calculated Pearson r correlation values of RC versus difficulty of BIM adoption. The r value of RC01 for medium firms is negative, suggesting that searching for better client communication strategies in these firms made the transition to BIM easier. The r values of RC02 show a u-shape with the large sized firms being higher than small sized firms. This shows that larger firms place more importance to finding ways to exchange ideas between employees leads to a more difficult transition to BIM as compared to medium sized ones. The r values of RC03 decrease as firm size increase indicating that as smaller firms attempt to streamline the consultant coordination process this directly leads to more difficult transition to BIM. Larger firms may find streamlining more effective for getting an easier BIM transition process. A similar pattern is seen in RC04 where the r value decreases as the firm size increases. This suggests that use of technology for small sized firms made the transition to BIM more difficult than medium or large ones. For all firm sizes, r values of RC05 are consistent with a slight decrease as firm sizes increase. This suggests that investing in education on technology design review processes make the BIM transition process more difficult.

4. Conclusions

The state of firms which have successfully transitioned to BIM in Sabah and Sarawak is only at 43% based on the responses obtained from the survey instrument. This shows that more effort is needed by both the government and firms themselves to successfully switch over to BIM. Furthermore, 42% of respondents report that the transition to BIM was difficult indicating that steps must be taken to more effectively facilitate this change and make the process easier.

Based on the Pearson r correlation values calculated in the study, a few conclusions can be derived so that other firms may be able to make a smoother transition to BIM. First, software training for employees is the most important factor for a successful transition to BIM regardless of firm size. Second, the importance of having up to date software, making use of software and the use of technology in the consultant coordination process are essential for small firms if a successful transition to BIM is to be achieved. Third, small firms should find ways to streamline their consultant coordination process to make the transition to BIM less difficult. Fourth, all firm sizes need to ensure their workflows are understood by employees to make the transition to BIM easier. Fifth, medium sized firms find the least
difficulty in transitioning to BIM and small sized firms find the most difficulty in transitioning to BIM. Finally, for large firms, all employees must be included in the decision-making process for a change to be successful but trying to achieve buy-in by a large number of employees makes the BIM transition more difficult.

Further research in this area may focus on studying factors affecting BIM adoption in construction firms in Peninsular Malaysia so as to form a comparison to East Malaysia. A study of this type should also attempt to focus on the individual states since each of them have very different levels of construction activity and growth.

References

[1] Chin J 2018 Bank Negara: Economy to grow 5.5% to 6% in 2018 The Star Online (https://www.thestar.com.my/business/business-news/2018/03/28/bank-negara-economy-to-grow-5pt5pct-to-6pct-in-2018/)
[2] Department of Statistics Malaysia 2018 The performance of the state’s economy (https://www.dosm.gov.my/v1/index.php?option=com_content&view=article&id=449&Itemid=L25EUXQxbWdBaEVoWXU5aTFQWUpNdz09&menu_id=TE5CRUZCbihh4ZTZZODZIbmk2aWRRT09)
[3] Lee R 2018 Catalysts for transformation of the construction industry The Edge Markets (http://www.thedgemarkets.com/content/advertise/catalysts-for-transformation-of-the-construction-industry)
[4] Construction Research Institute of Malaysia 2014 Issues and Challenges in Implementing BIM Building Information Modeling for SME’s in The Construction Industry (Kuala Lumpur: Construction Research Institute of Malaysia)
[5] Santos R, Costa A A, and Grilo A 2017 Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015 Automat. Constr. 80 118-36
[6] Latiffi A A, Brahim J and Fathi M S 2017 Building information modelling (BIM) after ten years: Malaysian construction players’ perception of BIM IOP Conference Series: Earth and Environmental Science 81 012147
[7] Latiffi A A, Brahim J and Fathi M S 2016 Transformation of Malaysian Construction Industry with Building Information Modelling (BIM) MATEC Web of Conferences 66 1-8
[8] Latiffi A A, Mohd S and Brahim J 2014 Building information modelling (BIM) Roles in the Malaysian Construction Industry (Sustainable Solutions in Structural Engineering and Construction) ed K Chantawarangul, W Suanpaga, S Yazdani, V Vimonsatit and A Singh (North Dakota, USA: ISEC Press)
[9] Latiffi A A, Brahim J, Mohd S and Fathi M S 2014 The Malaysian Government’s Initiative in using Building Information Modelling (BIM) in Construction Projects (Sustainable Solutions in Structural Engineering and Construction) ed K Chantawarangul, W Suanpaga, S Yazdani, V Vimonsatit and A Singh (North Dakota, US: ISEC Press)
[10] Bin Zakaria Z, Mohamed Ali N, Haron T, Marshall-Pointing A and Abd Hamid Z 2013 Exploring the adoption of building information modelling (BIM) in the Malaysian construction industry: A qualitative approach International Journal of Research in Engineering and Technology 2 384-95
[11] Mustafa Kamal E and Flanagan R 2012 Understanding absorptive capacity in Malaysian small and medium sized (SME) construction companies Journal of Engineering, Design and Technology 10 180-98
[12] Mamter S, Abdul-Aziz A R and Mamat M E 2017 Stimulation a Sustainable Construction through Holistic BIM Adoption: The Root Causes of Recurring Low BIM Adoption in Malaysia 2nd International Conference on Civil Engineering and Materials Science 216
[13] Yusuf B Y, Embi M R and Ali K N 2017 Academic readiness for building information modelling (BIM) integration to Higher Education Institutions (HEIs) in Malaysia. Proc. of the 2017 International Conference on Research and Innovation in Information Systems (Langkawi) pp 1-6

[14] Tahir M M, Haron N A, Alias A H, Harun A N, Muhammad I B and Baba D L 2018 Improving cost and time control in construction using building information model (BIM): A review Pertanika J. of Sci. and Tech. 26 21-36

[15] Tahir M M, Haron N A, Alias A H, Al-Jumaa A T, Muhammad I B and Harun A N 2017 Applications of building information model (BIM) in Malaysian construction industry IOP Conference Series: Materials Science and Engineering 291 012009

[16] Mohd-Nor M F I and Grant M P 2014 Building Information Modeling (BIM) in the Malaysian Architecture Industry WSEAS Transactions on Environment and Development 10 264-73

[17] Ali K N, Al-Jamalullail, S N N S I and Boon T C 2013 Building Information Modeling Awareness and Readiness among Quantity Surveyors and Quantity Surveying Firms Technical Paper (Skudai: Universiti Teknologi Malaysia-Royal Institution of Surveyors Malaysia)

[18] Rogers J, Chong H Y and Preece C 2015 Adoption of Building Information (BIM) technology: Perspectives from Malaysian engineering consulting services firms Engineering, Construction, and Architectural Management 22 424-45

[19] Smith D and Tardif M 2009 Building information modelling: A strategic implementation guide for architects, engineers, constructors, and real estate asset managers (Hoboken, NJ: John Wiley & Sons, Inc)

[20] Haliburton J T 2016 Building Information Modelling and Small Architectural Practice: An Analysis of Factors Affecting BIM Adoption (College Station, TX: Texas A&M University)

[21] Elshamy H 2015 The impact of firm size on innovative activity: An analysis based on Egyptian firm data International Journal of Business and Technopreneurship 5 397-406

[22] Bosma N and De Wit G 2004 The influence of firm innovation on firm size Scientific Analysis of Entrepreneurship and SMEs (Zoetermeer: Scientific Analysis of Entrepreneurship and SMEs) 200318

[23] Roger M 2004 Networks, firm size and innovation Small Business Economics 22 141-53

[24] De Vellis R 2003 Scale development: theory and applications: theory and application (Thousand Oaks, CA: Sage)