BIM IMPLEMENTATION FOR MICRO, SMALL AND MEDIUM-SIZED ENTERPRISES

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ABSTRACT

Literature discussion on BIM benefits and barriers for micro, small, and medium-sized enterprises is lacking. Testing the independence of statistic for nominal variables as such requires application of statistical techniques including Fisher's Exact Test, and Factor Analysis. The nominal variables were tested across 14 variables as operational definitions for benefits, and six variables were selected as operational definitions for concept of barriers. After factor analysis, four components related to benefits and two for barriers showed the highest significant association. The four benefits factors influencing digitalization are operation, marketability, productivity, and information-exchange. The two barriers are lack of professionalism and know-how.

INTRODUCTION

Digitalization and BIM implementation is a beneficial resolution for some construction companies, which helps them with integration of design, construction, and operations in a sustainable way. However, for some enterprises, in particular the micro, small, and medium-sized enterprises (MSMEs), it still may be viewed as a big challenge due to high costs, uncertainty, and its other concomitant factors. The important aspect is to understand what type of firms have a negative attitude towards digitalization and whether the size of a company, and BIM benefit and barriers are determining elements that effect the firm owners' decision-making process towards digitalization. MSMEs are normally defined based on their employee size (Li et al., 2019; Lam et al., 2017), therefore, it is crucial to understand if there exists a relationship between company size and BIM benefits, and which BIM benefits are defined within that relationship.

Lack of digitalization also stems from lack of research in this area for MSMEs (Hosseini et al., 2016; Li et al., 2019). It is imperative for micro companies to understand the benefits and barriers of BIM implementation to be able to make informed and logical decisions in its adaptation (Lam et al., 2017). Li et al. (2019) argues for the importance of understanding the factors delaying BIM implementation to find a strategic solution to this problem.

It is not an easy task to cut off the circle of underdevelopment, however; a strategic partnership with appropriate partners and suppliers for instance, may solve this problem. In partnerships where digital resources are shared, construction contractors could benefit from better project performance, more competitive advantage, and minimized overall project risks (Aghimien et al., 2020). As mentioned, there is an evident gap in research on digitalization and BIM implementation for MSMEs and whether BIM utilization impacts strategic relationships among stakeholders. To bridge this gap and contribute to the body of knowledge, this paper will examine the benefits and challenges of BIM implementation, rank the top benefits and challenges, group up the underlying factors in terms of common components, and relationship between firm size, strategic partnership, and BIM benefits will be analyzed to provide a road map in decision-making process for MSMEs.

BACKGROUND

BIM benefits and challenges are one of the subjects discussed frequently in AEC literature. Yan and Damian (2008) found six benefits rated by 67 US and UK respondents from 1 to 8 including creativity (3), sustainability (4), quality improvement (4), human resource reduction (6), cost reduction (5), and time reduction (7). They report that 40% of US and 20% of UK respondents mentioned that huge allocation of time and human resources for BIM training process was the most important barrier to application of BIM.

Latiffi et al. (2013) argued that the benefits of BIM implementation in construction industry are associated to five central points including design, scheduling, documentation, budget, and communication.

Mutonyi and Cloete (2018) found 13 benefits for BIM implementation regarding construction industry in Kenya as follows: rework reduction during construction, productivity maximization, clash detection, conflict/changes reduction, visualization improvement, collaboration and communication enhancement, improvement in project documentation, design review enhancement, quality improvement, faster and more effective method, time reduction, contingency reduction, and cost reduction.

In terms of BIM barriers, Mutonyi and Cloete (2018) discuss two kinds of technological and process related including: construction professionals do not enjoy any support and incentive from construction policy makers to use BIM, lack of standards and codes for BIM application, lack of BIM awareness, lack of client demand, lack of BIM specialist in the whole region, radical change in workflow as BIM requirement, high cost, too many legal barriers, lacking due to exchange and interoperability, inadequate research and development in BIM application, lack of IT infrastructure for BIM implementation.

Doumbouya et al. (2016) cited several BIM benefits in terms of design quality improvement, easy to implement, capability in sharing information, cost reduction and design error reduction, time shortening, faster work, energy efficiency enhancement, construction and project management support, and more efficiency in operation of building life for owners.

In short, one may find so many advantages in favor of BIM for construction industry in literature such as better site utilization (Deshpande and Whitman, 2014), effectiveness and accuracy of documentation and helpfulness in operation, maintenance, replacement and repair decision-making (Kjarstandottir et al., 2017), energy efficiency enhancement and better feasibility, effective storage and procurement management (Eastman et al., 2011), site congestion reduction , safety improvement, and sustainable design (Khosrowshahi, 2017), and last but not the least, better maintenance scheduling and easy information access (Enshassi et al., 2018).

Regarding challenges, drawbacks, and barriers of BIM, one may mention complexity of BIM models, and BIM implementation lack of contractual requirement (Ahmed et al., 2014), lack of demand from contractors' side, lack of BIM awareness, contractors' lack of demand, lack of awareness to BIM benefits (Gerges et al., 2017), doubt on return of investment and lack of standardized tools and protocols, also; lack of BIM specialists and experts (McAuley et al., 2017), interoperability between software programs and issues in data ownership, inadequate BIM usage training (Park and KIM, 2017), lack of awareness to BIM benefits (Latiffi et al., 2016), client lack of interest, also; resistance to change construction culture (Sahil, 2016), top management lack of support, also, resistance to change construction culture (Ganah and John, 2015), high cost (Ismail et al., 2017), lack of sub-contractor's interest to use BIM (Hosseini et al., 2016), insufficient government support (Enshassi et al., 2016). Further, Okakpu et al. (2020) and Khoshfetrat et al. (2020) examined the challenges of BIM in terms of risk factors for implementation. The former concluded that socio-cultural, financial, technical, skill set, and contractual risks are the most important factors, and the latter found that lack of BIM comprehension, software training, and BIM skilled architects and engineers along with resistance to change are among the key risk elements.

METHODOLOGY

The research goal in this study is to learn the effects of construction firm's size on becoming digitalized and its concomitant benefits and challenges for BIM implementation. A survey design was developed based upon a structured online questionnaire accordingly. Several questions and responses were extracted for this paper as secondary data. The sample size of 70 included 11 contractors, 12 designers, 1 supplier, 6 owners, and 3 consultants from Italy and Brazil as well as 2 with no response. All the Columbian respondents left this question blank. There were 23 respondents from micro firms with 1 to 9 employees, 26 from small size firms with 10 to 50 employees, 10 from medium size firms having between 51 to 100 employees, 9 from large firms with over 100 employees, and 2 as no response. The most important benefits and barriers of BIM were ranked using a descriptive analysis via mean values. Based on literature review, fourteen variables for concept of benefits and six variables for concept of barriers were factor analyzed through SPSS to determine the main factors and to build up new components or constructs based on their correlations. The fourteen selected variables for BIM benefits are as follows: processes control, information storage, information transparency, bureaucracy reduction, supply chain responsiveness, cost efficiency, stakeholder's management, material management, quality control, time efficiency, higher output quality, information exchange, data standardization, and strong competitiveness. For the second concept as barriers, six variables include inadequate skills, inadequate organizational structure, usage complexity, financial resources, interoperability ICT and interoperability sub-contractors. Both groups of variables were factor analyzed and four factors of benefit-oriented were formed and two factors were created for barriers. Independence testing techniques between variables/groups were conducted using Chi-Square Independence Test and Fisher's Exact Test to examine these categorical variables: 1. Size of the firm, 2. BIM benefits, 3. BIM barriers, and 4. Strategic partnership. These analyses were performed to determine if there is any relationship between firm size, BIM barriers and benefits, and strategic partnership among contractors.

DISCUSSION

Table 1 shows the descriptive statistics for BIM benefits. According to the findings, the top four benefits are supply-chain responsiveness, bureaucracy reduction, stakeholder management, and information transparency with respective mean values of 1.75, 1.72, 1.64, and 1.61 accordingly. Based upon variables' mean scores, time efficiency is the least beneficial variable with mean equal to 1.14 among these 14 variables, and process control with the mean value equal to 1.24 is a little higher than time efficiency. However, all these 14 variables considered valuable and beneficial for BIM implementation in construction industry according to respondents.

Table 1: Descriptive Statistics for BIM Implementation Benefits

Descriptive Statistics BIM Benefits					
BIM Benefits	N	Minimum	Maximum	Mean	Std. Deviation
Process Control	70	1.00	3.00	1.2429	.52297
Information Storage	70	1.00	3.00	1.4857	.58341
Information Transparency	70	1.00	3.00	1.6143	.57213
Bureaucracy Reduction	70	1.00	3.00	1.7286	.53626
Supply Chain Responsiveness	70	1.00	3.00	1.7571	.52297
Cost Efficiency	70	1.00	3.00	1.4429	.58075
Stakeholder Management	70	1.00	3.00	1.6429	.56558
Material Management	70	1.00	3.00	1.5714	.57914
Quality Control	70	1.00	3.00	1.5286	.58288
Time Efficiency	70	1.00	2.00	1.1429	.35245
Higher Output Quality	70	1.00	2.00	1.3286	.47309
Information Exchange	70	1.00	2.00	1.3857	.49028
Data Standardization	70	1.00	2.00	1.4571	.50176
Strong Competitiveness	70	1.00	2.00	1.4286	.49844
Valid N (listwise)	70				

Table 2 shows the top two BIM barriers according to highest mean values.

Table 2: Top BIM Barriers

Descriptive Statistics BIM Barriers					
BIM Barriers	N	Minimum	Maximum	Mean	Std. Deviation
Inadequate Skills	70	1.00	3.00	1.4286	.55355
Inadequate Organization Structure	70	1.00	3.00	1.4571	.55653
Usage Complexity	70	1.00	3.00	1.4286	.55355
Financial	70	1.00	3.00	1.7714	.48668
Interoperability ICT	70	1.00	3.00	1.5857	.55149
Interoperability Subcontractors	70	1.00	3.00	1.4571	.55653
Valid N (listwise)	70				

With mean values of 1.77 and 1.58, financial and interoperability with ICT were ranked as the top two barriers for BIM implementation, while all five variables were viewed by respondents as challenges or impediments to BIM implementation.

Further, to determine and group up the number of factors within the two research major concepts, namely, BIM implementation benefits and challenges were factor analyzed both at Eigenvalue 1 across several items or variables. These items could be considered as operationalized definitions for those two concepts of BIM benefits and BIM barriers, which consisted of 14 and 2 variables, respectively.

The factor analysis has created four factors or components out of these fourteen variables to explain the BIM implementation benefits. According to table 3, "Total Variance Explained", the first component may explain more than 32% of the variability, the second component shows more than 11%, the third has more than 9%, and the last component has more than 7%, respectively and all together, the variation of the BIM benefits may be explained as almost 61% by means of these four components. Although other variables may have certain effects on variation of benefits, as the factor loadings of these first four items show, they have the highest effect on this variability explanation. Further, the Component Matrix, shown in table 4, indicates the internal correlation of each factor. For the first factor, the first three items have the strongest correlation (more than 0.7) and the last three variables have a low correlation (0.3) with the component. Based on this fact, the component may be called operations, since it includes "quality control", "bureaucracy reduction", and "process control", which are part of operating activities. The second component seems more of a market related activity with items including: "strong competitiveness" with 0.814 correlation coefficient, "time efficiency", and "higher output quality" each having more than 0.5 correlation coefficients. Therefore, this component could be called marketability. The third factor may be called production for having two positive correlations with information exchange (r=0.625) and time efficiency (r=0.432) and one negative correlation with higher output quality (r= -0.614). Finally, the last component may be named information sharing, which consists of variables such as data standardization (r = 0.712), information transparency (r = 0.348), information exchange (r = 0.320), with having negative correlations with both cost and time efficeincy. This negative correlation implies that the more reduction in cost and time, the less information is being shared and probably regarded as production secrets.

Table 3: Total Variance Explained for BIM Benefits

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.604	32.884	32.884	4.604	32.884	32.884	4.036	28.831	28.831
2	1.568	11.201	44.085	1.568	11.201	44.085	1.660	11.859	40.689
3	1.275	9.104	53.189	1.275	9.104	53.189	1.431	10.225	50.914
4	1.091	7.789	60.979	1.091	7.789	60.979	1.409	10.065	60.979
5	.981	7.007	67.986						
6	.863	6.162	74.148						
7	.707	5.052	79.200						
8	.630	4.501	83.701						
9	.581	4.149	87.850						
10	.503	3.592	91.442						
11	.382	2.730	94.171						
12	.354	2.525	96.697						
13	.260	1.857	98.554						
14	.202	1.446	100.000						

Extraction Method: Principal Component Analysis.

Table 4 – Component Matrix for BIM Benefits

Component Matrix[a] BIM Benefits	Component			
BIM Benefits	1	2	3	4
Process Control	.721			
Information Storage	.612			
Information Transparency	.581			.348
Bureaucracy Reduction	.721			
Supply Chain Responsiveness	.667	-.347		
Cost Efficiency	.697			-.365
Stakeholder Management	.642			
Material Management	.690			
Quality Control	.741			
Time Efficiency	.316	.554	-.432	-.334
Higher Output Quality		.524	-.614	
Information Exchange	.350		.625	.320
Data Standardization	.353			.712
Strong Competitiveness		.814		

Extraction Method: Principal Component Analysis.
a. 4 components extracted.

The next part of research findings and analysis looks at challenges of BIM implementation among construction firms. There are two main components or factors comprising barriers to BIM application out of six variables shown in table 5. The first component consists of inadequate skills, interoperability with ICT, and interoperability with subcontractors, all being problematic with correlation coefficients above 0.7. Interoperability referes to the ability of computer systems or a particular software to share and exchange information, which in this case is internaly within the company and externally with other stakeholders. This component could be called lack of professionalism amongst parties involved. The second component is complexity of usage, which shows the highest correlation coefficient of 0.968. It seems like a sort of communality effect of one or more variables on "complexity of usage" variable and consequently, the communality effect happens when one or more variables affect the third variable to indicate high correlation in the equation. Therefore, this component is called lack of technical know-how among involved parties. Further, in this realm, the least correlation belongs to inadequate organizational structure (r =0.488). According to "Total Variance Explained" shown in table 6, around 60% of barriers variation (cumulative percentage) may be explained by these two factors. The minimum Eigenvalue is 1 as seen in Scree plot 2. The factor loading for each component is high especially for component 2, which as mentioned is 0.980. (see table 8 - Component Matrix). By rotating this Matrix, high correlation among variables is encountered.

Table 5: Component Matrix for BIM Barriers

Component Matrix[a]	Component	
BIM Barriers	1	2
Inadequate Skills	.780	
Inadequate Organization Structure	.685	
Usage Complexity		.980
Financial	.641	
Interoperability ICT	.738	
Interoperability Subcontractors	.711	

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 6 – Total Variance for BIM Barriers

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.546	42.425	42.425	2.546	42.425	42.425	2.540	42.326	42.326
2	1.027	17.114	59.539	1.027	17.114	59.539	1.033	17.213	59.539
3	.872	14.526	74.065						
4	.704	11.728	85.793						
5	.538	8.963	94.756						
6	.315	5.244	100.000						

Extraction Method: Principal Component Analysis.

The next step was performed to understand the relationship and association between firm size, BIM benefits, and strategic partnership among firms. Fisher's Exacts Test based on Chi-Square Independence Test was conducted based on the following hypotheses:

H_0 = There is no association between firm size and BIM benefits.

H_1 = There is an association between firm size and BIM benefits.

H_0 = There is no association between strategic partnership and BIM benefits.

H_1 = There is an association between strategic partnership and BIM benefits.

Out of all the fourteen BIM benefits, only data standardization and stakeholder management had a p-value < 0.05. Therefore, the null hypothesis regarding all other variables can be rejected, and it is confirmed that there is a relationship between firm size and stakeholder management and data standardization. The value of Fisher's Exact Test statistic is 14.815, this would result in a P-value of 0.025, which is less than given an alpha level of 0.05. This implies that the null-hypothesis could be rejected, which states there is no relationship between two variables, firm size and BIM benefits and the alternative hypothesis accepted, which confirms that there is a relationship between two variables i.e., firm size and stakeholder management. In other words, the association between two nominal variables is significant.

Further, the Pearson Chi-Square Test statistic is less than the critical value, that is: 13.60 < 15.51. This happens because, 10 cells have expected count less than 5 and minimum requirements for each cell frequency is 5.

Regarding the second variable, which is a relationship between firm size and data standardization, again the value for Fisher's Exact Test statistic is equal to 14.149. This independence value results into the P-vale equal to .004, which again is less than the critical p-value of 0.05. This is the same as above through which null-hypothesis is rejected and alternative hypothesis is accepted, which states there is an association between firm size and data standardization.

Further, since the number of cells counts that have less frequency than 5 is only 4 cells, the Pearson Chi-Square Test statistic obtained is larger than the critical value. That is when degree of freedom is 4, and given that alpha level for example is 0.05, the critical value is 9.49. Thus: 13.60 > 5.51

Namely, this confirms that null- hypothesis can be rejected and alternative hypothesis accepted, which is an indication of significant association between firm size and data standardization.

Same procedure was performed for strategic partnership and BIM benefits. Out of all the BIM benefits, only bureaucracy reduction and stakeholder management had a p-value < 0.05. Therefore, the null hypothesis regarding all other variables can be rejected, and it is confirmed that there is a relationship between strategic partnership and stakeholder management and bureaucracy reduction.

CONCLUSION

This study's main contribution to the body of knowledge lies within its investigation of BIM implementation in the context of micros, small and medium-sized enterprises and what aspects of BIM in terms of benefits and challenges impact the MSMEs the most. The digitalization process contains both benefits and challenges for micro, small, medium enterprises in construction industry. Since both concepts of benefits and barriers are abstract, certain variables were envisioned for both and in terms of several proper statistical techniques including Fisher's Exact Test, Pearson Chi-square Test of Independence, and Factor Analysis. Their association was tested against 14 variables regarding BIM implementation benefits and across six variables regarding BIM implementation challenges. The most important benefits for MSMEs were supply-chain responsiveness and bureaucracy reduction, and financial and interoperability with ICT were ranked as the top two barriers. The general hypothesis was association between firm size, strategic partnership, and benefits of BIM implementation. This association between firm size and BIM benefits was tested and found to be significant only for data standardization and stakeholders' management. In case of strategic partnership and BIM benefits, the association was found to be positive for bureaucracy reduction and stakeholder management. For the first concept, 'Benefits', four components were formed and called as 'operation', 'marketability', 'productivity', and 'information exchange'. The second concept of 'Barriers' had two components called, 'lack of professionalism' and 'lack of BIM know-how' of parties involved.

Some of the limitations included the translation of the questionnaire into several languages that caused some challenges for this study. Since, this was a cross-cultural study, precision in transferring the concepts into other languages was a primary factor in measuring the same measures and concepts. Unfortunately, this accuracy may not have been precise and as a result, it did not turn into a unified and straightforward questionnaire across the board. This may cause the validity and reliability of measurement in this study to be less precise. There were also cases or questions that were ignored by some countries while other participating countries might have responded to some questions reluctantly. Annual turnover, for instance, is overwhelmingly neglected by both Brazilian and Columbian respondents and Columbian repondents completely igonred the question regarding their profession, i.e., contractors, owner, subcontractor, etc.

For future studies, it is recommended that direct dependencies among factors and indicators of digital technology be investigated through multivariate analysis such as ANOVA as well as structural equation modleing (SEM). In addition, implementation of other digital tools, besides BIM, should be also studied in connection with digital business models for micro, snmall and medium-sized enterprises.

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