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Modelling the Relationship of Building Information Modelling Implementation Barriers and Drivers in Sabah Construction Industry

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ABSTRACT

Despite Sabah's reputation as a rapidly developing state, the number of Building Information Modelling (BIM) performance is significantly lower than the adoption in Peninsular Malaysia. In fact, there was a lack of research explored on BIM specifically in Sabah. Therefore, this research is comprehensively aimed to understand and analyse the dynamics of BIM implementation in the construction industry in Sabah. The objective of the study was to determine the association of barriers that exists in Sabah's construction industry that prevent BIM from being implemented there. The next stage involved conducting an analysis of the association of drivers that can drive Sabah's construction industry toward greater adoption in BIM. This study utilized a quantitative approach, collecting data from government regulators and Grade 6 and Grade 7 contractors in Kota Kinabalu, Sabah. A questionnaire was administered to 62 respondents and the data were analysed using PLS-SEM. PLS-SEM was selected for its flexibility in handling diverse data requirements and complex models, offering an alternative to covariance-based SEM. The findings underscored a noteworthy correlation between barriers and drivers of BIM implementation, suggesting that overcoming obstacles is closely tied to advancing factors facilitating BIM adoption. Among the barriers examined, "Lack of direction of BIM in the industry" within the "Process" category emerged as significantly associated. Additionally, the study identified influential driving forces, both internal and external, which serve as catalysts for effective BIM integration. Notably, "Organizational culture that motivates BIM collaboration in projects" within the "Internal Push" category stood out as a significant driving factor.

1. Introduction

In the realm of building and construction, the building and construction sector is experiencing significant transformation with the advent of the fourth industrial revolution, known as IR 4.0. This

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revolution is pushing the sector toward greater digitalization, although it lags behind other industries in terms of progress and automation [1]. Building Information Modelling (BIM) emerges as a crucial technology within this context, advancing alongside IR 4.0. BIM's efficacy has substantially enhanced construction industry achievements over time.

In 2007, the Public Works Department (PWD) of Malaysia published their BIM Standard Manual and Guidelines, which marked the beginning of BIM's official introduction to the Malaysian market [2]. BIM has recently caught the attention of Malaysia's construction industry and some of them have already used it on numerous projects. The BIM process gives those involved in building the chance to plan, coordinate and design in an integrated manner.

However, the level of BIM implementation in the state of Sabah is still below the level of satisfaction level compared to Peninsular despite the fact that the construction sector has gradually become more diverse and grown over the past several years [3]. BIM implementations will certainly become essential in order to support the enormous construction growth in Sabah. Besides, fewer studies that have attempted to unravel a Gordian Knot of barriers to BIM implementation have focused on determining the current level of acceptance, describing and delineating the barriers and assess the association of the drivers especially in Peninsular.

No formal efforts have been made to study or investigate the factors that impede BIM implementation in the Sabah construction industry, especially among contractors and government regulators. Besides, the absence of comprehensive research on the drivers in Sabah’s BIM implementation represents a critical knowledge gap within the construction industry, as exemplified studies such as those conducted by Syed Jamaludin *et al.,* [3] and Sinoh *et al.,* [4]. These studies have delved into the barriers associated with BIM implementation and there are no others researches touch about the positive factors that propel the adoption and successful integration of BIM.

Understanding the correlation between barriers and drivers is crucial as it highlights how contractors and government regulators can be motivated by potential benefits. It also indicates the necessary communications to overcome obstacles. This combined approach provides a predictive tool to estimate performance improvements by aligning the right concepts with corresponding benefits and reassurances. Thus, this research study will be presented to determine what the actual barriers that hamper its implementation are and what are the driving factors that could enhance its pace of implementation in Sabah construction industry by modelling the relationship between both of it.

This study aims to identify the barriers hindering BIM implementation in Sabah's construction industry and analyse the drivers that could enhance its adoption. The relationship between these barriers and drivers was examined using PLS-SEM.

This research is going to be carried out in the Sabah state area known as Kota Kinabalu. Kota Kinabalu is one of the main business hubs in Sabah providing higher order services and also being one of the most prosperous cities in Sabah and is home to both an international airport and a dedicated container port [5]. This locale was chosen as the setting for the research because the district's construction industry exposure to BIM is still at a relatively early level as compared to the other districts. In light of this, there is a requirement for a revaluation of the construction industry, particularly in the rapidly developing city of Kota Kinabalu. Hence, it is essential that the contribution made by integrating BIM into construction project is actively promoted specifically to the public and private construction project in order to show what BIM does is good; however, this is not happening in the case study area.

1.1 Overview of Building Information Modelling (BIM)

The building sector has adopted a novel strategy with the help of BIM technology. It changed the process of delivering projects from using traditional two-dimensional (2D) drawings to using information-rich three-dimensional (3D) architectural models. On the other hand, it is not just concerned with 3D modelling but also with collecting and managing all of the project's data assets in accordance with a BIM standard over the lifecycle of the project.

The construction sector is currently undergoing radical change as a result of the implementation of IR 4.0, which is bringing about the beginning of the era of intelligent construction. The emergence of "cyber-physical systems" is one way to think about IR 4.0. These systems will involve entirely new capabilities possessed by both humans and machines.

BIM is one of the core technologies that is thought to support the primary ideas behind IR 4.0 [6]. BIM is the backbone of the digitalization revolution in IR 4.0. It existed from computer-aided design (CAD) to become an advanced technology that supports the entire life cycle of a construction project by providing a virtual model of the building as well as relevant information about the building.

BIM is recognized as the most recent and sophisticated type of information and communications technology in Malaysia, according to CIDB Malaysia [7], BIM is a modelling technology and related set of procedures for creating, exchanging, analysing and using digital information models over the course of a construction project. BIM is a process of integrating information and technology to produce a digital representation of a project, despite the fact that different definitions of BIM exist. It incorporates information from various sources, including design, construction and operating data and develops alongside the actual project over the course of the project's entire timeframe [8].

1.2 Development of BIM in Malaysia

In Malaysia, BIM adoption and development have received robust support from the government, industry associations and educational institutions. Although BIM implementation in Malaysia may not yet match the levels seen in some developed nations, there has been notable progress in recent years.

Since the beginning of the 2000s, the private sector in Malaysia has been the primary force behind the adoption of BIM. However, BIM did not become a popular term until the PWD (Jabatan Kerja Raya, JKR) introduced it in construction project planning for public works in 2007 via their BIM Standard Manual and Guideline [9].

The National Cancer Institute of Malaysia in Sepang was the first project in Malaysia to involve the application of BIM. This was followed by other projects in Malaysia that were part of the BIM Pilot program, such as the Healthcare Centre Type 5 Pahang and the Administration Complex of Suruhanjaya Pencegah Rasuah Shah Alam. In these pilot projects, BIM was utilized for a variety of purposes, including site modelling, visualization, design review, clash analysis, 4D schedule and simulation and record modelling [10].

According to CIDB Malaysia [11], BIM steps up to play a key role as one of the keystones of the digitalization process. As one of the technologies under the Productivity Thrust in the Construction Industry Transformation Programme (CITP) 2016-2020 [12], BIM serves as a platform to enable various stakeholders to collaborate on the planning, design and construction of buildings using 3D models [13]. By enlarging CITP, a number of KPIs that have been listed under the Technology Focus Area, including implementing BIM Level 2 by Q4 2020 for 100% of public building projects above RM 100 million (for JKR building projects) and adopting BIM for 70% of private and public building projects above RM 10 million by January 2021 [14].

1.3 Awareness of BIM

Numerous researchers have emphasized the importance of raising industry awareness of the BIM implementation process, its advantages and its difficulties in order to persuade the sector to use it as a new means of project delivery [15]. According to BIM Report [16], since the initial national BIM Report [17] was released, BIM awareness in Malaysia increased from 45% in 2016 to 76% in 2019. In order to determine the percentage of respondents who are familiar with BIM, the latest BIM Report evaluated a number of other factors related to BIM awareness which are BIM training and program availability.

The findings in Figure 1 showed a rise in respondents' participation in BIM programs from 55% to 66%. This growth demonstrates that the majority of respondents are probably aware of and interested in BIM-related programs. The action taken by the construction stakeholders to empower the use of BIM in the projects is reflected in the rising number of respondents who are interested in learning more about BIM. Through CITP, CIDB has undertaken a number of initiatives to advance the growth of the BIM industry in Malaysia, including training and practical advice for BIM adoption at MyBIM Centre, as well as certification and accreditation programs for BIM personnel [18].

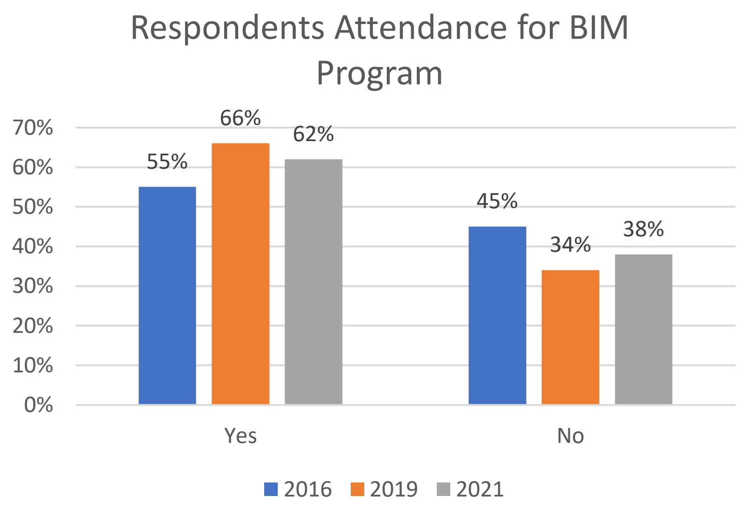

Fig. 1. Attending BIM program [16-18]

However, the percentage decreased in 2021 to 62%. Nevertheless, the percentage is still higher than in 2016 (55%). This trend is primarily the result of pandemic survival because industries must continue to function even in the face of a pandemic, so they are more in survival mode.

In order to ensure the competence of participants in the construction industry, training is one of the fundamental skills that every employee in every organization must possess. The inability to prepare plans in BIM and integrate them with other stakeholders along the value chain was highlighted by CIDB [19]. BIM personnel training at authorized training facilities must be consistently delivered to address this problem. As BIM awareness grows over time, there is some correlation between organizational awareness and BIM awareness, as shown in Figure 2 the fact that more organizations are offering BIM training, as shown by an increase in survey responses from 35% to 57%, indicates that these organizations are aware of and open to changing how they implement BIM.

Fig. 2. BIM training provided by organizations [16-18]

However, the percentage decreased in 2021 to 38%. Nevertheless, the percentage is still higher than in 2016 (35%). These results can be associated with the results for 'attending BIM programs' as training provided by organizations is also affected by COVID-19. Training increased significantly between 2016 and 2019, but the pandemic caused it to decline. Consequently, raising awareness will aid in overcoming obstacles to BIM adoption and implementation and, as a result, the benefits of this technology [20].

1.4 Gap Analysis from Past Research Findings

The research gap analysis that is summarized in Table 1 revealed that the majority of prior studies concentrated on construction industry players rather than the perspectives of government regulator or the contractor. As a result, the majority of the research on BIM implementation among construction players, AEC firms and related small and medium-sized enterprises (SMEs), focuses on awareness, barriers and drivers. Additionally, it was discovered that Sabah's research lagged behind that of other nations in terms of examining the factors that influence BIM implementation among those involved in the construction industry and government regulators.

Table 1
Research gap analysis

No.	Title	Author	Focus	Scope	Findings
1	The Emerging Challenges of Adopting BIM in the Construction Industry: Evidence from Sabah, Malaysia	Syed *et al.,* [3]	To determine the challenges in adopting BIM in the Sabah construction industry	Architect, engineer and quantity surveyor firms.	Construction player reluctant to accept new things, high cost of adoption BIM, insufficient software interoperability, lack of standardized procedures and guidelines

2	Factors affecting success and difficulty to adopt Building Information Modelling (BIM) among construction forms in Sabah and Sarawak	Sinoh *et al.,* [4]	i. To identify the present state of BIM adoption in East Malaysia i. To examine relationship between perceived firm culture and reported perception of successful adoption and adoption difficulty.	All construction companies in Sabah and Sarawak registered as contractors with CIDB.	42% of respondents report that the transition to BIM was difficult, indicating that steps must be taken to facilitate this change and make the process easier more effectively. Software training for employees is the most important factor for a successful transition to BIM regardless of firm size.
3	The barriers factors and driving forces for BIM implementation in Malaysian AEC companies.	Ibrahim *et al.,* [2]	To investigate the barriers factors in BIM implementation by Malaysian AEC construction industry and identifying the driving forces available to overcome the BIM implementation issues in Malaysia.	Focus on architects, engineers and contractors in Kuala Lumpur and Pulau Penang	Most of the things that slow down BIM implementation are related to the organization's culture and the government is the main force behind it by making a detailed and flexible guideline for BIM implementation.

2. Methodology

The flowchart of the research methodology is illustrated in Figure 3 below. This flowchart helped to determine the association barriers and drivers and to model the correlation between both barriers and drivers.

2.1 Quantitative Approach

Quantitative analysis is typically applicable when there is an adequate amount of easily available, representative data. Furthermore, a quantitative approach is better suited if the goal is to avoid bias, demonstrate validity and reliability, maintain the researcher's objectivity, test hypotheses, evaluate causal relationships, forecast phenomena and quantify variables [21]. In order to collect the necessary data, a questionnaire survey method of the quantitative approach is chosen. A variety of techniques are included in quantitative research that use numerical or statistical data to systematically examine social phenomena. As a result, quantitative research requires measurement and makes the assumption that the phenomenon under study is quantifiable. In order to validate the measurements taken, it aims to analyse data trends and relationships [22]. Quantitative research employs formal instruments and structured processes for data collection. The data are gathered in such a methodical and impartial way and for the final step is statistical procedures. This method is advantageous in this study because it allows for the statistical analysis of BIM implementers and contractors' perceptions of the barriers and drivers of BIM implementation in Sabah's construction industry.

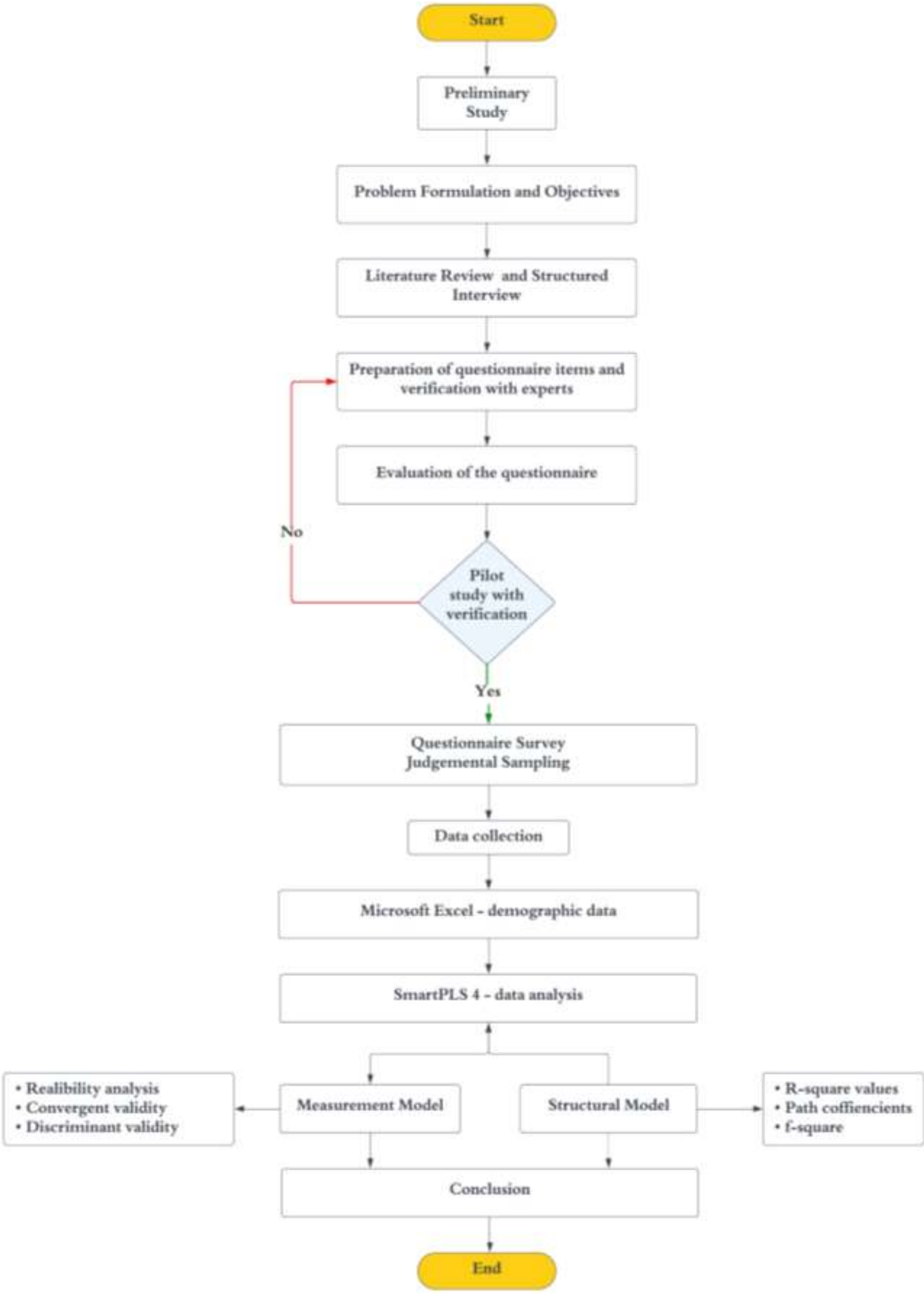

Fig. 3. Flowchart of the research methodology

2.2 Pilot Study

A pilot study aids in the analysis of data collection plans in terms of the data quality and the methodology to be used [23]. Additionally, the pilot test is crucial because it enables the identification of real-world issues with the methodology and provides insight into potential failures of this study. Therefore, this pilot study is analysed using validity analysis through experts and reliability analysis based on Cronbach's Alpha, to eliminate data inaccuracies in this investigation.

For validity analysis, the questionnaire design was examined by one academic supervisor of UTHM, two other instructor and one industrial expert who worked as a BIM manager. For reliability analysis, six researchers were involved in the assessment of a series of structured questions. This enabled the elimination of inferred irrelevant questions that did not meet the objectives or were not appropriate to be present. To ensure the section A, which likely contains demographic or background information about the respondents, is also considered. Including section A ensures that the data collected are comprehensive and allow for a more nuanced analysis. As displayed in Table 2 depicts the reliability analysis of both section B and C for the pilot study questionnaire, where all data are valid. For the purpose of this study, questionnaires that have been prepared are sent out to the respondents who have been targeted in order to establish the barriers and drivers in implementing BIM among contractors and BIM implementers.

Table 2
Reliability analysis for Section B and Section C

Sections	Measures	Cronbach's Alpha	Interpretation
Section B	Barriers	0.896	Good
	Cost	0.831	Good
	People	0.892	Good
	Process	0.890	Good
	Technology	0.837	Good
	Drivers	0.969	Excellent
Section C	External Push	0.948	Excellent
	Internal Push	0.964	Excellent

2.3 Data Collection and Data Analysis

In this research, Partial least squares structural equation modelling (PLS-SEM) or known as SmartPLS 4 version full software are used where provides an alternative to covariance-based SEM, which is deemed more flexible in data requirements, specification of relationships and ability to handle complex models [24]. It is a statistical technique used for analysing complex relationships between latent variables in a structural equation model (SEM). By using SmartPLS 4 to examine the relationship between barriers and drivers in BIM implementation, the typical parameters that will be considered are latent variables. In the context of barriers and drivers in BIM implementation, latent variables could include "Barriers to cost", "Drivers to barriers" and others. While for path coefficients, it defines the paths or relationships between the latent variables and their corresponding indicators. Outer loadings represent the relationship between the latent variables and their indicators, while AVE and CR provide information about the convergent and discriminant validity of the measurement model.

Besides, structural mode specifies the relationships between the latent variables (i.e., barriers and drivers) in the structural model. Assign path coefficients to indicate the strength and direction of these relationships. Additionally, model fit indices assess the overall fit of PLS-SEM model using various fit indices. Equally important is significance testing where need to conduct significance testing of the path coefficients using bootstrapping techniques. Bootstrapping generates multiple resamples from the data to estimate the standard errors, confidence intervals and p-values of the path coefficients. This helps determine the statistical significance of the relationships between barriers and drivers in BIM implementation.

Apart from PLS-SEM, Microsoft Excel was used to generate all the charts required for descriptive analysis. A total of 62 responses were obtained from the intended respondents, signifying a 51.67% response rate in this research and fulfilling the prerequisites for being a correlational study. Since a 4-Likert scale was used for the survey questionnaire to determine the barriers and drivers in implementing BIM among contractors and BIM implementers, the simple central tendency measures were applied in this research. The mean over a subset of simple values, more effective terms weights would be developed [25]. Table 3 describes the mean range by three central tendency level, which are:

Table 3
Mean range by central tendency level

Mean Range	Central Tendency Level
3.01 – 4.00	High
2.01 – 3.00	Moderate
1.00 – 2.00	Low

3. Results and Discussion

3.1 Demographic Information

The demographic section includes seven factors from the respondents' background: gender, size of organization sector, working position in company, length of service, involvement of BIM and years of experience in handling BIM. Only few of the demographic information is shown in this paper. Figure 4 depicts the majority respondents were Female (58%) while Figure 5 depicts the organization sector respondents where have an equal frequency of 31.

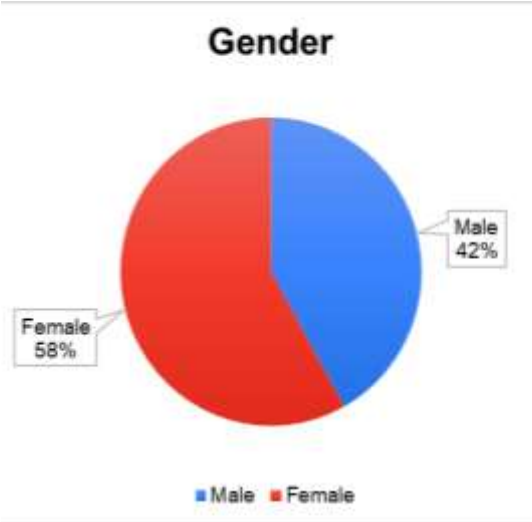

Fig. 4. Gender

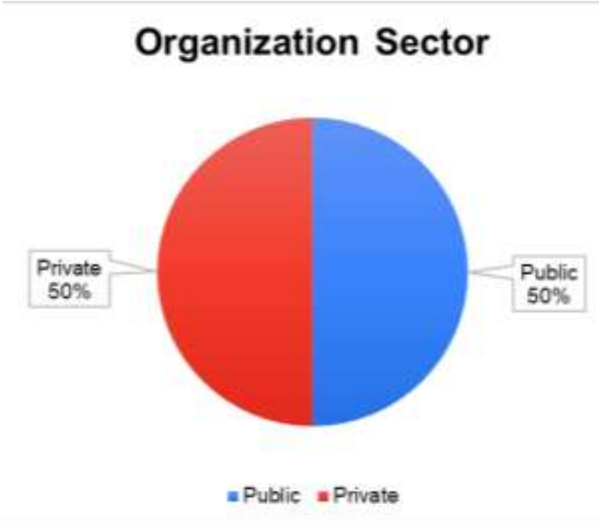

Fig. 5. Organization sector

Next, Figure 6 illustrate respondent' working position in company where majority is others with diverse position roles within the study population, while Figure 7 illustrates respondents' years of experience in handling BIM in the construction industry where the majority of respondents are not involved in handling BIM (74%).

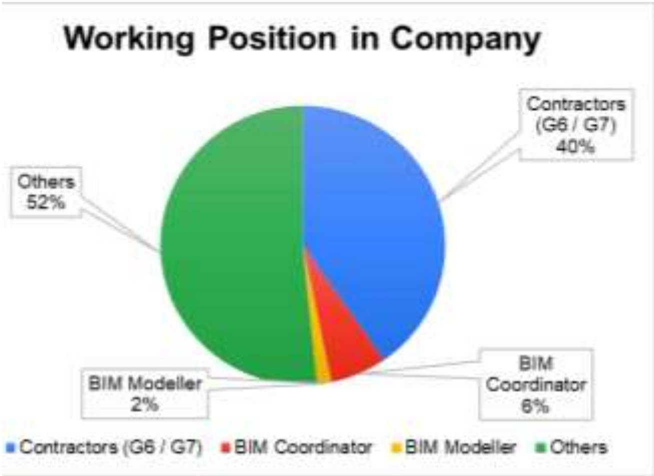

Fig. 6. Working position in company

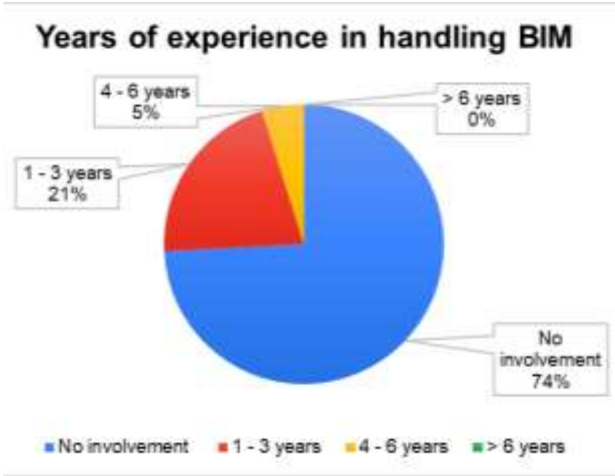

Fig. 7. Years of experience in handling BIM

3.2 The Association of Barriers and Drivers to BIM Implementation in Sabah Construction Industry

In this section, the first objective was to determine the association of barriers preventing BIM implementation within Sabah in the construction industry. The questions are designed to gauge the respondents' association of barriers in "Cost", "People", "Process" and "Technology". Within these questions, the barriers in implementing BIM among contractors and government regulators can be determined. Next objective is to examine the association of drivers for the increased usage of BIM within the construction industry in Sabah. There are two questions designed which are "External Push" and "Internal Push" which can unearth key insights into the underlying forces shaping the industry's technological landscape. Within these questions, the drivers in implementing BIM among contractors and government regulators can also be determined.

The measurement validity test for this study was conducted on all the variables by using Smart PLS 4. The measurement model defines the relationship between the objects and their underlying latent constructs. Assessing the reflective measurement items (BIM Drivers and Barriers) using PLS-SEM involves evaluating both convergent validity and discriminant validity. The reflective indicators are run to calculate the PLS-SEM Algorithm. As shown in Table 4, all the BIM drivers and barriers achieved composite reliability greater than 0.60, thus meeting the approval criteria [26,27]. Additionally, Cronbach's Alpha reached 0.948, indicating moderate to high reliability as recommended by Asparouhov *et al.,* [28]. Furthermore, the AVE was employed to test the construct variables' convergent validity, calculated from Eq. (1) as follows:

$$AVE = \frac{\sum \lambda\iota^2}{\sum \lambda\iota^2 + \sum var\ (\varepsilon_\iota)} \quad (1)$$

Where, AVE is the average variance extracted; $\lambda\iota$ is the component loading of each item to a latent variable; and $var\ (\varepsilon_\iota) = 1 = \lambda\iota^2$ respectively.

For AVE to be acceptable, it must be greater than 0.5, indicating that the measurement variables explain at least 50% of the variance. In this study, as shown in Table 3, all constructs have AVE values above 50%, demonstrating that the measurement model is convergent and internally stable. Hulland [30] suggests that an external load value of 0.70 is preferred, but for exploratory analysis, a value of 0.40 or higher is acceptable. Table 4 shows the outer loadings for all measurements in the initial model. All outer loadings were accepted except for one BIM barrier - cost (C1) and two BIM barriers - technology (T1 and T2), which were omitted due to low loadings (less than 0.65) [31]. This indicates they had a low impact on their related constructs. After removing these items, the modified model was re-evaluated, as shown in Table 4.

Table 4
Construct's reliability and validity analysis

Variables	Items	Outer Loading (>0.7)		Cronbach's Alpha	Composite Reliability (CR) (>0.7)	Average Variance Extracted (AVE) (> 0.5)
		Initial	Modified			
External Push	EP1	0.795	0.793	0.948	0.955	0.638
	EP2	0.778	0.779			
	EP3	0.794	0.789			
	EP4	0.765	0.770			
	EP5	0.763	0.768			
	EP6	0.856	0.856			
	EP7	0.866	0.863			
	EP8	0.812	0.810			
	EP9	0.691	0.687			
	EP10	0.784	0.785			
	EP11	0.875	0.876			
	EP12	0.790	0.793			
Internal Push	IP1	0.902	0.904	0.964	0.969	0.756
	IP2	0.858	0.859			
	IP3	0.853	0.852			
	IP4	0.879	0.878			
	IP5	0.843	0.843			
	IP6	0.861	0.859			
	IP7	0.836	0.836			
	IP8	0.849	0.848			
	IP9	0.895	0.896			
	IP10	0.917	0.919			
Cost	C1	0.628	deleted*	0.831	0.887	0.663
	C2	0.821	0.832			
	C3	0.829	0.834			
	C4	0.778	0.820			
	C5	0.759	0.768			
People	P1	0.736	0.730	0.892	0.918	0.651
	P2	0.805	0.809			
	P3	0.781	0.786			
	P4	0.886	0.889			
	P5	0.758	0.748			
	P6	0.865	0.867			
Process	PR1	0.871	0.874	0.890	0.920	0.698
	PR2	0.795	0.795			
	PR3	0.738	0.729			
	PR4	0.938	0.940			
	PR5	0.820	0.823			
Technology	T1	0.500	deleted*	0.837	0.900	0.751
	T2	0.302	deleted*			
	T3	0.855	0.875			
	T4	0.877	0.877			
	T5	0.830	0.846			

3.2.1 Discriminant validity

The purpose of assessing discriminant validity is to ensure that a reflective construct has stronger relationships with its own indicators than with indicators of any other construct in the PLS path model [32]. It also measures the degree of difference between overlapping constructs. Discriminant validity can be evaluated using the Fornell-Larcker Criterion [29], indicator cross-loadings and the Heterotrait-Monotrait (HTMT) ratio of correlations. In this paper, only HTMT will be shown. From the HTMT result, the values (in red) in Table 5 indicated discriminant validity problems according to the HTMT0.85 criteria. This implied that the HTMT criteria detect the collinearity problems among the latent constructs (multicollinearity). The constructs of Barriers – People, Barriers – Process, Drivers – External Push and Drivers – Internal Push are having problems. The majority of constructs' items most likely measure the same thing. Stated differently, it includes the overlapping items from the respondents' perception of the affected constructs.

Table 5
HTMT results

	Barriers	Cost	Drivers	External Push	Internal Push	People	Process	Technology
Barriers								
Cost	0.883							
Drivers	0.623	0.432						
External Push	0.584	0.442	0.942					
Internal Push	0.572	0.367	0.996	0.796				
People	0.944	0.613	0.817	0.751	0.781			
Process	0.995	0.796	0.405	0.409	0.340	0.685		
Technology	0.548	0.607	0.344	0.247	0.385	0.565	0.408	

However, outer loadings for all measurements in the initial model were acceptable except for one in BIM barrier – cost and two in BIM barrier – technology, which were omitted due to low loading factors. The modified model underwent further evaluation, including assessing discriminant validity. Nevertheless, subsequent examination of the HTMT ratio indicated problems with discriminant validity particularly for constructs like Barriers – People, Barriers – Process, Drivers – External Push and Drivers – Internal Push. The HTMT values exceeding 0.90 suggested collinearity issues and a lack of distinction. Overall, the results underscore the importance of careful consideration of both convergent and discriminant validity in structural equation modelling analysis.

3.3 Model the Correlation between Barriers and Drivers of BIM Implementation in Sabah's Construction Industry

The path coefficient measures the direct effect between constructs. A larger path coefficient means a stronger direct effect. This study uses the Bootstrapping method to test each path relationship hypothesis. This method checks the reliability and significance of the data set, including the path coefficient (p-value and outer weight at the 95% confidence interval). Table 6 and Figure 8 show the path coefficient Beta value (β) (indicating the strength of the relationship between independent and dependent values), t-value (path analysis) and the decision on the hypothesis for the relationship in the BIM barriers and driver's model. The coefficient of determination (R^2) is a measure of the model's predictive accuracy and it is a combination of exogenous variables on endogenous variables. The results indicate that drivers, people and process have a substantial level of predictive accuracy as the R^2 value is 0.996, 0.736, 0794 respectively. While the R^2 value for cost is 0.595, it has moderate level of predictive accuracy in this study.

Table 6
Summary of path analysis, Beta value and t-test value

No.	Hypothesis	β	Standard deviation (STDEV)	t-value	p-value	Decision	No
H_1	Barriers -> Cost	0.776	0.057	13.683	0.000	Supported	H_1
H_2	Barriers -> People	0.861	0.029	29.461	0.000	Supported	H_2
H_3	Barriers -> Process	0.893	0.026	34.326	0.000	Supported	H_3
H_4	Barriers -> Technology	0.493	0.114	4.320	0.000	Supported	H_4
H_5	Drivers -> Barriers	0.586	0.096	6.081	0.000	Supported	H_5
H_6	External Push -> Drivers	0.398	0.027	14.589	0.000	Supported	H_6
H_7	Internal Push -> Drivers	0.659	0.028	23.630	0.000	Supported	H_7

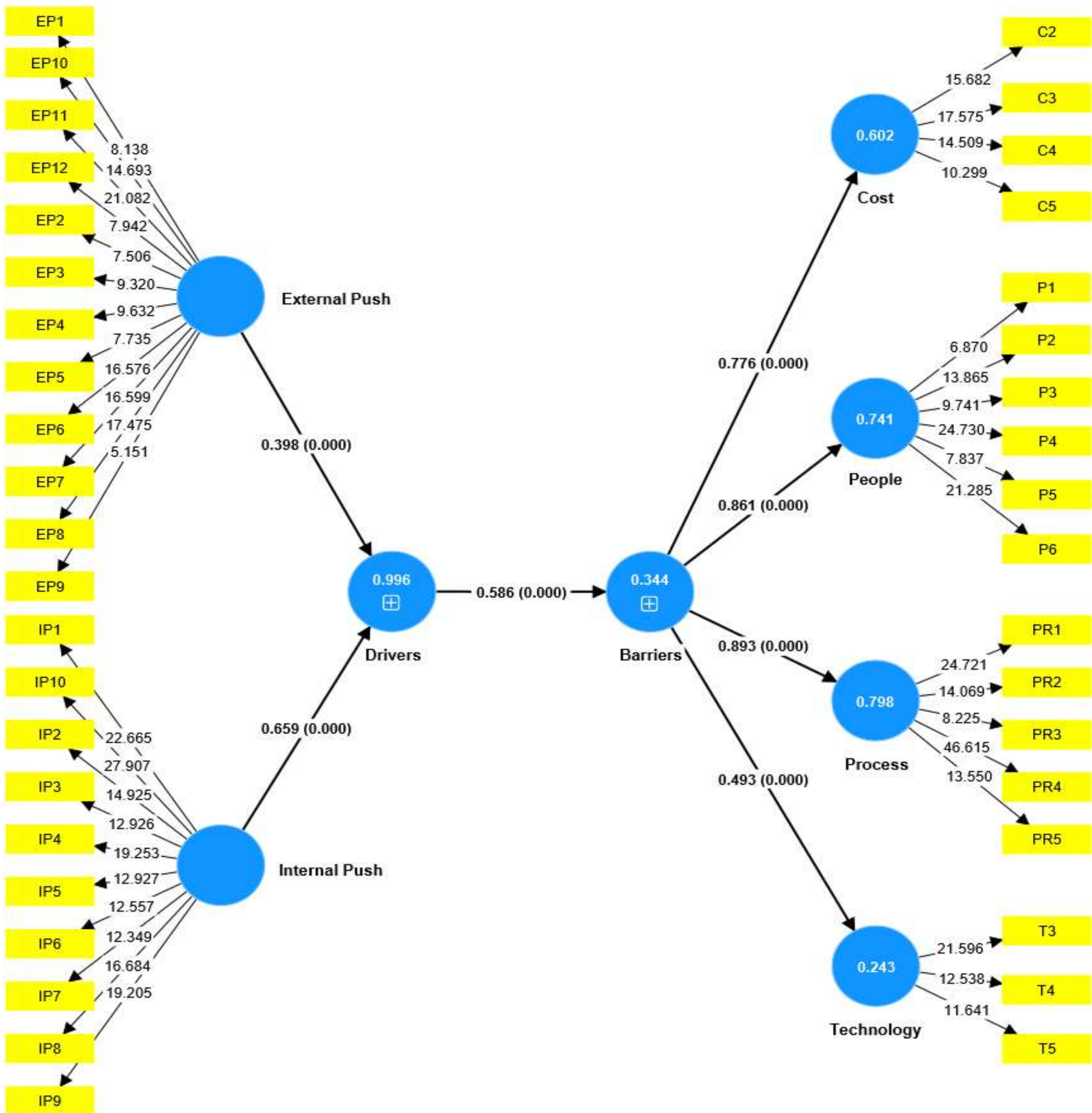

Fig. 8. Path analysis

3.4 The Effect Size (f^2)

After evaluating the R2, the level of effect size (f2) is important to know the effect size of the predictor constructs. The effect size is also known as the change in R2 when an exogenous variable is removed from the model. According to Cohen [33], to assess the f2 are that range value of 0.02, 0.15 and 0.35 can be described as small, medium and large effect of the exogenous latent variable respectively. If the effect size values of less than 0.02 indicate that there is no effect.

In this study, the exogenous construct of barriers to technology has the lowest f2 value (0.321), but it still exceeds Cohen's guidelines value and is therefore classified as a large size effect. While for the other six constructs reveal a robust and practically significant relationship between the identified constructs in our model. All seven constructs exhibit substantial effect sizes, with f2 values consistently exceeding 0.35, indicative of large and impactful relationships. This implies that the exogenous variables considered in our study collectively exert a strong influence on predicting the variance in the corresponding endogenous constructs.

3.5 Discussion

Based on the findings on model the correlation of barriers and drivers to BIM implementation in Figure 9, the significant of from each variable are stated where there are two elements under category of “Process”, namely “Lack of direction of BIM in the industry” and “Lack of standardized process and guidelines”. Findings from CIDB Malaysia [11] revealed that lack of standards for modelling structures is primary reason for legislative barriers within the construction industry. Lack of direction of BIM in the industry is mainly caused by unavailability of standards and guidelines [34]. This rather consistent with findings by Syed *et al.,* [3], many contractors were still unfamiliar in handling BIM since contractors are too comfortable with the conventional process in Malaysia.

The second most critical barrier is “People”. This result is supported by the previous study done by CIDB Malaysia [11] where there is inadequate understanding and proficiency among professionals regarding BIM concept and tools. Thus, due to lack of understanding and knowledge can result in hesitancy to implement it [35]. While for the drivers in BIM implementation, the first rank is “Organizational culture that motivates BIM collaboration in projects” where when employees embrace a culture that encourages collaboration through BIM, it promotes a mindset shift towards effective teamwork and knowledge sharing. This result is supported by the previous study done by Abbanesjad *et al.,* [36] where collaboration is the commitment of parties to work together to achieve mutual goals to create value and operational benefits and keep track of BIM-enabled tasks.

Next is “Organization provide BIM training program” is another strong driver in enabling BIM implementation in Sabah construction industry. Offering training programs demonstrates a commitment to equipping employees with the necessary skills and knowledge to effectively utilize BIM tools and processes. Besides, previous study done by Talib *et al.,* [37] where training and education has become the most important way to solve the issue in the implementation of BIM. This investment in training contributes to the overall competency of the workforce, reducing barriers related to the lack of BIM expertise [2]. Findings from Sinoh *et al.,* [2] also support the ranked third driver which is “Provide financial resources of organization” by adequately financial support is essential for acquiring BIM tools, implementing training programs and sustaining BIM-related initiatives.

For both the relationship between barriers and drivers highlights that the positive factors influencing BIM implementation exert a substantial impact in overcoming the identified challenges.

This implies that focusing on and leveraging these driving forces can play a pivotal role in mitigating the barriers hindering BIM adoption in Sabah.

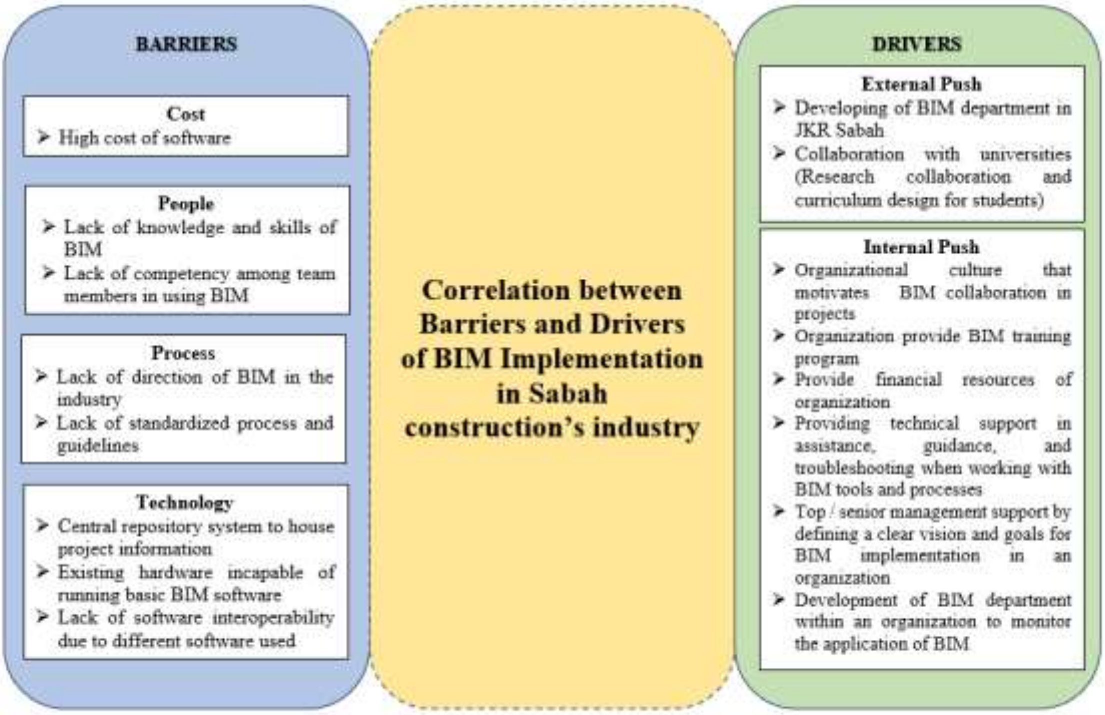

Fig. 9. Correlation model of BIM implementation barriers and drivers in Sabah

4. Conclusions

This research aimed to understand the barriers to implementing BIM and the drivers for its increased use in the Sabah construction industry. The findings showed that government regulators and contractors are most aware of barriers related to the lack of direction, knowledge and a central repository system for BIM projects. For BIM drivers, the focus was on organizational culture, training programs and financial resources.

The study successfully identified and correlated barriers and drivers of BIM implementation. For instance, addressing the lack of industry direction can be supported by developing a collaborative organizational culture that promotes BIM. Providing BIM training programs can help overcome knowledge and skill gaps, while establishing a central repository system can be complemented by providing technical support.

However, the study faced challenges in locating intended respondents, especially government contractors and regulators who lacked experience with BIM projects. Future research could focus on assessing BIM implementation levels among these stakeholders in other states with significant construction development in Malaysia.

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