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# The Impact of Building Information Modelling (BIM) Strategies in Energy Sustainability Elements to Sustainable Campus Using PLS-SEM Approach

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**Abstract:** This paper establishes a structural relationship between BIM strategies in eleven (11) energy sustainability elements divided into management and technical aspects that impact a sustainable campus. The work established thirteen (13) benchmarks for independent variables and one (1) dependent variable. The exploratory research design used in this study led to the structural model development being the central focus of the study. A judgmental sampling technique was used to distribute a questionnaire survey among local engineers, assistant engineers, and technicians in Kota Kinabalu, Sabah, Malaysia. The research population survey employed 78 returned questionnaires. The analysis used Partial Least Squares Structural Equation Modelling (PLS-SEM) to test the hypotheses. The result indicates that the management and technical aspects of Energy Sustainability Elements (ESE) significantly impact sustainable campus with path coefficients of 2.447 and 5.032, respectively. Furthermore, the findings have revealed that Hypothesis 1 and Hypothesis 2 were all positive and significant at the 0.05 level, indicating that these two hypotheses are valid and supported. This study provides valuable information and insights for Malaysian universities to achieve a sustainable campus by adopting building information modeling (BIM) strategies in the context of energy efficiency.

**Keywords:** Sustainable campus, energy sustainability, energy efficiency, building information modelling, PLS-SEM

## 1. Introduction

In recent years, architecture, engineering, and construction (AEC) organizations have increasingly focused on Building Information Modelling (BIM). In the last decade, BIM has emerged as a primary tool for managing buildings throughout their lifecycles. The sustainable campus has become a global issue concerning universities since the "Our Common Future" report was published during the World Conference on Environment and Development in 1987. Universities worldwide are concerned about how to make their campuses more sustainable. In 2015 the United Nations General Assembly established 17 Sustainable Development Goals (SDGs). Towards Sustainable Development Goal 7.3 (Double Improvement and Energy Efficiency), there are promising indications that energy is becoming more dependable and widely available globally. However, energy significantly affects sustainability since it impacts society, the economy, and the environment. Thus, a sustainable campus requires an emphasis on energy sustainability because campus operations and activities have significant energy consumption depending on the size of the campus, including its buildings and infrastructure. The Malaysian government's use of BIM strategies requirement in the Architecture, Engineering, Construction, and Operation (AECO) industry in Malaysia is expected to cope with these issues.

BIM and sustainability are relatively new concepts in construction and related to the architecture-engineering industry's improvement. Green BIM is a term used to explain the integration of BIM into sustainability in construction projects or industries. Although many researchers highlight studies for BIM strategies to adapt to sustainable projects, such as [1] and [2], more information about integration studies for BIM strategies toward sustainable campuses needs to be provided. This knowledge gap can be filled by scrutinizing the underlying BIM strategies in Energy Sustainability

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Elements (ESE), grouped into Management and Technical aspects impacted on a sustainable campus. Then a structural equation model to establish their causal relationship was developed. Hence, this paper aims to identify: (1) the underlying strategies for BIM Strategies according to Energy Sustainability Elements, (2) the independent variables (IV) and dependent variables (DV), and (3) the significant impact of BIM strategies on sustainable campuses.

In order to establish a structural relationship between BIM strategies, the eleven (11) energy sustainability elements are divided into management and technical aspects that impact a sustainable campus. Thirteen (13) benchmarks for independent variables, and one (1) dependent variable were established. This study yields two hypotheses, shown in Appendix A: H1: management aspects significantly impact a sustainable campus, and H2: technical aspects significantly impact a sustainable campus.

A judgmental sampling technique was employed to distribute a questionnaire survey among local engineers, assistant engineers, and technicians at Kota Kinabalu. A sample size of 78 was obtained from a total respondent population 493. After the questionnaire was distributed, 78 respondents returned the questionnaire as fulfilling the sampling size determination according to the "10-time rule" in SEM PLS Sampling [3], which is that the sample size should be greater than ten times the maximum number of inner or outer constructs at any latent variable in the model. The analysis used Partial Least Squares Structural Equation Modelling (PLS-SEM) to test the hypotheses. In the measurement model, for validity, Cronbach alpha (CA), Composite Reliability (CR), and Average Variance Extract (AVE) were assessed. In contrast, in discriminant validity, the Cross Loading method was selected to determine the reliability of the study. The structural model evaluated hypothesized research by determining the p-value and t-value as higher than the cut-off value. The findings of the two (2) hypothesized research questions indicate that the management and technical aspects of Energy Sustainability Elements (ESE) significantly impact sustainable campuses. Based on the results, a structural relationship was established using SMART PLS software. The structured relationship provides valuable information to Malaysian universities for achieving sustainable campuses by adopting building information modeling (BIM) strategies in the context of energy efficiency.

## 2. Background Information

### 2.1 Energy Sustainability Elements (ESE)

Since energy is a subset of the sustainable campus elements and impacts achieving a sustainable campus status, a comprehensive sustainable campus element in a sustainable campus framework must be investigated to assist universities in managing the energy consumption on campuses. According to [4], there are six energy management elements: Organizational Structure, Energy Policy, Planning, Audit, Reporting, and Awareness. While in the technical element, [5] and [6] added one element, retrofitting, which was a crucial element in reducing energy consumption. Based on a case study retrofitting at Universiti Teknologi Malaysia (UTM)'s Library [5] and a case study retrofitting at R&D Building, Universiti Malaysia (UM) [7] highlights retrofitting as a potential element to enhance energy performance. In addition, [8] explained another four technical elements: Building Envelope, Efficiency Equipment, Mechanical Systems, and Renewable Energy.

### 2.2 Strategies for BIM in Energy Sustainability Elements (ESE)

Table 1 summarizes twenty-seven (27) strategies for BIM in Energy Sustainability Elements (ESE) that have been identified as variables for this study. Table 1 outlines the list of strategies coded as (i) Organizational Structure/Energy Team (OR); OR1, OR2, OR3, (ii) Energy Policy (EP); EP1, EP2, (iii) Planning (PL); PL1, PL2 (iv) Audit (AU); AU1, AU2 (v) Reporting (RP); RP1, RP2, (vi) Awareness/Education (AE); AE1, AE2, AE3, (vii) Retrofitting (RT); RT1, RT2, (viii) Building Envelope (BE); BE1, BE2, BE3, (vix) Efficiency Equipment (EE); EE1, EE2, EE3, (x) Mechanical System (MS), MS1, MS2, MS3, and (xx) Renewable Energy (RE); RE2, RE2 discovered in the previous literature review, which can implement to reduce energy consumption towards energy efficiency.

#### 2.2.1 Organizational Structure/Energy Team

An organizational structure or energy team is essential in promoting learning and developing positive attitudes toward new technologies [9] such as BIM and gaining a competitive advantage in adopting new and necessary knowledge about the necessary skills and values. An organization's investment in BIM research and development demonstrates its readiness to use the technology. BIM leaders must establish and sustain coalitions with their BIM-authoring software vendors, consultants, contractors, and the broader BIM community [10].

#### 2.2.2 Energy Policy in BIM

BIM policy is one of the most significant factors in BIM implementation. Existing practices and survey results indicate that the AEC industry is still dependent on conventional working practices, with BIM lacking from the contractual framework, and it is crucial to apply BIM gradually in the contractual context [26]. Moreover, to employ BIM on construction projects, a BIM policy that provides a detailed vision of project delivery techniques, process quality, and information consistency should be adopted across AEC organizations [27]. Consequently, organizations must also implement internal BIM policies to improve their BIM capabilities, such as guidelines often associated with public projects, so organizations establish BIM standards for private projects compatible with most industry players.

**Table 1 - Strategies for BIM implementation in energy efficiency**

| Elements | Code | Strategies of BIM | References |
|---|---|---|---|
| **Organisational Structure/ Energy Team** | OR1 | Support from the top manager | [11] |
| | OR2 | Enhance collaboration between stakeholders | [2] |
| | OR3 | Availability of qualified staff | [12] |
| **Energy Policy** | EP1 | Accomplish building energy certification | [13] |
| | EP2 | Appropriate legislation | [2] |
| **Planning** | PL1 | Improved site layout plans | [14] |
| | PL2 | Effective coordination and planning of construction work | [12] |
| **Audit** | AU1 | Monitor and track progress during construction | [15] |
| | AU2 | Improve the lifecycle data management | [12] |
| **Reporting** | RP1 | Improve documentation process | [15] |
| | RP2 | Construction managers gather reporting data and information from the relevant disciplines and communicate them more effectively through BIM tools | [16] |
| **Awareness/Education** | AE1 | Awareness level for BIM of the industry and universities | [17] |
| | AE2 | Collaboration with universities | [17] |
| | AE3 | Training and development | [2] |
| **Retrofitting** | RT1 | Evaluate existing buildings' energy performance using BIM tools with compare the current performance with the performance after the proposed renovation to identify the best renovation solutions | [13] |
| | RT2 | BIM interoperability tools are utilised in the monitoring, managing, and maintenance phases in building retrofitting projects | [18] |
| **Building Envelope** | BE1 | Thermal energy analysis and simulation | [19] |
| | BE2 | Analyze the effects of the building envelope and building orientation on energy performance | [13] |
| | BE3 | Determining the impact of the energy performance of the size and shape of glass panels in solar radiation gains, different insulation materials and different wall solution | [20] |
| **Efficiency Equipment** | EE1 | Availability of appropriate software and hardware tools | [2] |
| | EE2 | Open - source software development | [21] |
| | EE3 | Availability of BIM and sustainability databases | [21] |
| **Mechanical Systems** | MS1 | Enhanced data transfer and interoperability across tools in mechanical system | [22] |
| | MS2 | Modelling for HVAC system design in building | [23] |
| | MS3 | Set point temperature for the building | [24] |
| **Renewable Energy** | RE1 | Creating a building that focuses on renewable energy efficiency | [25] |
| | RE2 | The building must account for the energy impacts in the BIM design phase | [25] |

### 2.2.3 Reporting, Planning and Audit

The ability to detect and report clashes to the user is one of the most essential features of BIM. Clash detection may expedite inter-discipline coordination by detecting model issues more quickly and accurately. This allows communication between industries to concentrate on finding solutions rather than issues. The procedure for audit detecting and reporting clashes will vary depending on the stage of the project. BIM capability assessment for all the scope of work involved in that project's purpose. Both planning in design development and construction design stages, BIM clash identification audit, and reporting was crucial.

### 2.2.4 Awareness and Education

Effectively planned training and education programs help staff acquire new skills and enhance their understanding of BIM concepts and techniques. Comprehensive training and education are essential for fulfilling end-user expectations and sustaining a long-term commitment to continuous development. Since BIM is a relatively new technology, industry players will have varied degrees of experience, resulting in outcomes of variable quality. Organizations and stakeholders should design strategies to simplify BIM training and education for new recruits to enhance BIM effectiveness. In addition, training programs might be customized to meet a range of needs, from global and basic to specialized and advanced.

### 2.2.5 Retrofitting

Almost all a building's physical features are permanent, hence increasing its energy efficiency is complicated. Due to this, retrofitting buildings is one way to increase energy efficiency in existing buildings. BIM technologies have been used to analyze the energy performance of existing buildings. Through simulation, it has been possible to compare the current performance to the performance of the building after suggested renovations and to determine which renovation alternatives are the most suitable.

### 2.2.6 Building Envelope

The most common use of building information modeling (BIM) technologies is to help analyze how the building's envelope and orientation affect its energy efficiency. Buildings that qualify as Nearly Zero-Energy Buildings (NZEB) have a high level of energy efficiency, as shown by their low-cost heat coefficients and highly efficient equipment. BIM technologies may help designers construct more sustainable structures, even in the early design phases, by expediting the estimate of energy demands and materials optimization by comparison. This enables designers to choose solutions that decrease the need almost to zero. BIM technologies may help designers construct more sustainable structures than conventional ones.

### 2.2.7 Efficiency Equipment

BIM implementation is a complicated process that requires expert technical skills. Information technology (IT) experts are needed to choose the proper hardware, install the right software, and provide ongoing support for BIM implementation. In addition, the variety of BIM software being utilized in a project raises the issue of data interoperability. Therefore, obtaining expert support in the resolution of significant difficulties may make the adoption of BIM easier. Based on this information, the level of professional support acquired in selecting hardware and software and implementing BIM may be a measurement for determining an individual's or organization's level of competence.

### 2.2.8 Mechanical Systems

Mechanical systems in building could use a variety of standards and technological practices, such as interoperable programs and information-sharing methods, to promote the formation of integrated teams. Coordination techniques between project teams and standardization of building components and related features are important for better results in the implementation of BIM [26]. The most important component that contributes greatly to energy consumption in buildings is the HVAC system, which is the most important to meet thermal comfort needs. Therefore, standardization of BIM rules and processes is required to ensure successful BIM implementation [29].

### 2.2.9 Renewable Energy

BIM can be integrated with energy modeling tools, including renewable energy sources such as photovoltaic systems or wind turbines, to achieve zero energy (ZE). The concept of net ZE is a building that reduces energy demand through efficiency and balances energy demand through various renewable technologies. When designing a building that focuses on renewable energy, the energy impact must account for an energy impact in the design phase. Sustainable building characteristics can be achieved using BIM to achieve an optimal design result for ZNEB (Zero Net Energy Building) [25].

## 3. Methodology

### 3.1 Survey Development

A questionnaire survey for gathering random data systematically was used in this study. The list of potential strategies of BIM according to Energy Sustainability Elements (ESE) was scrutinized, and numerous articles were obtained from online research databases, including Scopus and Google Scholar, by combining the five following keywords: Building Information Modeling, BIM Strategies, Energy Efficiency Strategies or Initiatives, Sustainable Campus and PLS-SEM. Considering relevant facts and findings from the literature, the Energy Sustainability Elements (ESE) identified and extracted from sustainable campus and green building frameworks regularly adopted by universities worldwide and scrutinized BIM strategies according to the ESE towards sustainable campus.

### 3.2 Questionnaire Structure

The study objectives and contact information were provided on the survey's main page, followed by two sections. The first section of the questionnaire solicited to acquire general demographic information of respondents, including background and organizations. This component is necessary for determining the respondents' reliability. The second part consists of a list of the strategies for BIM strategies in ESE, and respondents were asked to rank their level of agreement on a five-point Likert scale (1 = Very Disagree, 2 = Disagree, 3 = neutral, 4 = Agree, and 5 = Very Agree). The third part includes a list of the Energy Sustainability Strategies for achieving a sustainable campus. Respondents were also asked to rank the level of agreement on the items on a five-point Likert scale (1=Very Disagree, 2=Disagree, 3=neutral, 4=Agree, and 5=Very Agree).

## 3.3 Data Collection

Judgmental or purposive sampling was used as the sampling strategy of choice for the survey. Purposive sampling is a non-probability sampling method that selects the unit of analysis depending on the purpose of the analysis. The questionnaire was distributed to Architecture, Engineering, Construction, and Operation (AECO) industries involving engineers, quantity surveyors, and architects from JKR Sabah and contractors in G1-G7 who are registered in CIDB Sabah based at Kota Kinabalu using Google Forms and sent to the respondent by email or mobile applications such as WhatsApp, Telegram, or any latest mobile application (Table 2).

**Table 2 - Respondent's characteristic sampling based on their job position**

| No. | Faculty/Department | Quantity of Respondents (*N*) | Total |
|---|---|---|---|
| 1 | JKR Sabah (HQ Kota Kinabalu) | 175 | |
| 2 | JKR Federal (*Pasukan Projek Khas 2*, Kota Kinabalu) | 30 | 487 |
| 3 | Contractor Grade 4-7 (Registered CIDB at Sabah) | 247 | |

As a result, a total of 78 valid responses from 487 populations were collected to fulfill sampling size determination according to 10 time-rule PLS SEM Sampling [28], which is built on the assumption that the sample size should be greater than ten times the maximum number of the inner or outer construct at any latent variable in the model. In this research, the authors have classified the respondents according to their position, qualification, and years of experience, as shown in Table 3. According to the respondent designation, 35.9% of respondents are engineers, architects, and QS, the most significant percentage of respondents. Then assistant engineer, assistant QS and assistant architect are 21.8%, followed by 19.2% respondents as Technician. For top management, the Director in the company or department is 5.1%, and Senior Engineers, including the Head of Department, is 7.7%. Contractor Grade 1 to 3 are 2.6%, and Contractor Grade 4-7 are 7.7%. Any designation in the civil or construction sector (AECO Industry) is acceptable as long as the responder is familiar with BIM and sustainable campus. The percentage of respondents with a Master, bachelor's degree, a diploma, certificate (Malaysian Skills Certificate), or High School (Malaysian Certificate of Education) was evaluated as 11.5%, 53.8%, 20.5%, 5.1%, and 9.1%, respectively.

**Table 3 - Demographic of respondents**

| Characteristics | Categories | Frequency (*n*) | Percentage (%) |
|---|---|---|---|
| Designation (job post) | Director | 4 | 5.1 |
| | Senior Engineer | 6 | 7.7 |
| | Engineer/QS/Architect | 28 | 35.9 |
| | Assistant Engineer/QS/Architect | 17 | 21.8 |
| | Technician | 15 | 19.2 |
| | Contractor Grade 1-3 | 2 | 2.6 |
| | Contractor Grade 4-7 | 6 | 7.7 |
| Qualification (education level) | Master | 9 | 11.5 |
| | Bachelor | 42 | 53.8 |
| | Diploma | 16 | 20.5 |
| | Certificate/SKM | 4 | 5.1 |
| | SPM | 7 | 9.1 |
| Years' experience in engineering field | Less than 5 years | 19 | 24.3 |
| | 5 - 10 years | 18 | 23.1 |
| | 10 years and above | 41 | 52.6 |

Regarding qualification, most responses from key players in the industry elucidated that the qualification level was intended to be independent of the quality of the response. There are 24.3% responders with less than five years of experience, 23.1% with 5-10 years of experience, and 52.6% with more than ten years of experience. These results reflect great experience in construction. Because BIM is a relatively new technology in the sector, the respondents' backgrounds are appropriate for this research.

# 4. Analysis and Results

## 4.1 PLS-SEM Structural Relationship

Establishment of a PLS-SEM structural relationship for hypotheses developed for this study using SmartPLS software version 3.0 and presented in Appendix A. First, a hypothesized structural pathway model is developed that illustrates the relationship between BIM strategies (independent variables) in Energy Sustainability Elements (ESE) impact on a sustainable campus (dependent variable). The structural framework is then verified by running the PLS-SEM algorithm, evaluating, and analyzing the estimated values by comparing them to the required thresholds of all parameters to determine if the elements of the 6D BIM strategies (independent variables) have significant impacts on achieving a sustainable campus (dependent variables). For the analysis in PLS-SEM, the validity of the measurement model is first assessed using the composite reliability, the loadings of the variables on the corresponding construct, and the average variance extracted (AVE). Next, internal consistency reliability is measured by composite reliability and Cronbach's alpha, which should be above 0.7. Next, indicator reliability is assessed using the loadings of the variables on the corresponding construct with a value of at least 0.4. Then, convergent validity is assessed using AVE. The result of this assessment should be greater than 0.5. After that, discriminant validity is assessed. Discriminant validity refers to the degree to which a given construct differs. For adequate discriminant validity, the square root of the AVE for each construct should be higher than the correlation between constructs, and the loading of a measure on its respective construct should exceed cross-loading. Finally, the structural model validity is assessed using the significance and relevance of the structural model relationships.

## 4.2 Measurement Model Evaluation

### 4.2.1 Convergent Validity

Reliability measurement models must be established before the structural model can be tested. Consequently, evaluating the measurement models' reliability and validity is necessary. For example, in Table 4, all the loadings for independent variables and AVE values were higher than the recommended values of 0.4 and 0.5. It shows that the indicators and constructs have satisfactory convergent validity [28]. Furthermore, the assessed composite reliability (CR) values and Cronbach's alpha (CA) values of all constructs are higher than the needed threshold of 0.7, which shows that the internal consistency and reliability are satisfactory.

**Table 4 - Loadings, AVE, CR and CA for convergent validity**

| Constructs | Indicators | Loadings | AVE | CR | CA |
|---|---|---|---|---|---|
| **Management Group** | | | | | |
| **Organisational Structure /Energy Team** | OR2 | 0.899 | 0.707 | 0.878 | 0.791 |
| | OR3 | 0.734 | | | |
| | OR1 | 0.880 | | | |
| **Energy Policy** | EP1 | 0.916 | 0.828 | 0.906 | 0.792 |
| | EP2 | 0.904 | | | |
| **Planning** | P1 | 0.898 | 0.824 | 0.903 | 0.787 |
| | P2 | 0.917 | | | |
| **Audit** | A1 | 0.978 | 0.955 | 0.977 | 0.953 |
| | A2 | 0.976 | | | |
| **Reporting** | RP1 | 0.945 | 0.897 | 0.946 | 0.886 |
| | RP2 | 0.950 | | | |
| **Awareness/Education** | AE1 | 0.958 | 0.896 | 0.963 | 0.942 |
| | AE2 | 0.945 | | | |
| | AE3 | 0.936 | | | |
| **Technical Group** | | | | | |
| **Retrofitting** | RT1 | 0.968 | 0.939 | 0.969 | 0.935 |
| | RT2 | 0.970 | | | |
| **Building Envelope** | BE1 | 0.945 | 0.900 | 0.964 | 0.944 |
| | BE2 | 0.972 | | | |
| | BE3 | 0.929 | | | |
| **Efficiency Equipment** | EE1 | 0.932 | 0.858 | 0.948 | 0.917 |
| | EE2 | 0.920 | | | |
| | EE3 | 0.927 | | | |
| **Mechanical Systems** | MS1 | 0.931 | 0.908 | 0.967 | 0.949 |
| | MS2 | 0.967 | | | |

| | | | | | |
|---|---|---|---|---|---|
| | MS3 | 0.961 | | ` | |
| **Renewable Energy** | RE1 | 0.963 | 0.927 | 0.962 | 0.922 |
| | RE2 | 0.963 | | | |

### 4.2.2 Discriminant Validity Using Cross Loading Method

The discriminant validity of the model must be evaluated to validate that each concept is different from the others. For this study, discriminant validity is evaluated using the cross-loading method. Cross-loading is used to establish that each manifest variable has a more significant loading correlation with the corresponding independent variables. The outer loading of an indicator on its associated construct should be greater than all its loadings on other constructs [30]. Table 5 shows that the cross-loading for each manifest variable within its associated group of independent variables is often more prominent than that of the other associated group of independent variables (highlighted in bold). This indicates that the discriminant validity of the model has been achieved. After evaluating all necessary tests for measurement, it is concluded that the model has met all criteria for measurement evaluation.

**Table 5 - Cross loading method for discriminant validity**

| Constructs | Organizational Structure | Energy Policy | Planning | Audit | Reporting | Awareness/ Education | Retrofitting | Building Envelope | Efficiency Equipment | Mechanical Systems | Renewable Energy |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OR1 | **0.880** | 0.579 | 0.635 | 0.757 | 0.618 | 0.378 | 0.487 | 0.429 | 0.291 | 0.493 | 0.475 |
| OR2 | **0.899** | 0.592 | 0.788 | 0.660 | 0.565 | 0.468 | 0.632 | 0.645 | 0.448 | 0.666 | 0.671 |
| OR3 | **0.734** | 0.465 | 0.437 | 0.453 | 0.383 | 0.411 | 0.536 | 0.577 | 0.398 | 0.403 | 0.645 |
| EP1 | 0.638 | **0.916** | 0.669 | 0.624 | 0.543 | 0.585 | 0.726 | 0.643 | 0.560 | 0.650 | 0.475 |
| EP2 | 0.546 | **0.904** | 0.664 | 0.512 | 0.464 | 0.641 | 0.558 | 0.578 | 0.531 | 0.538 | 0.515 |
| PL1 | 0.573 | 0.620 | **0.898** | 0.672 | 0.600 | 0.493 | 0.432 | 0.524 | 0.360 | 0.504 | 0.560 |
| PL2 | 0.783 | 0.706 | **0.917** | 0.709 | 0.638 | 0.482 | 0.658 | 0.615 | 0.546 | 0.627 | 0.605 |
| AU1 | 0.747 | 0.629 | 0.764 | **0.978** | 0.832 | 0.441 | 0.521 | 0.489 | 0.273 | 0.477 | 0.508 |
| AU2 | 0.724 | 0.594 | 0.722 | **0.976** | 0.821 | 0.422 | 0.519 | 0.466 | 0.337 | 0.535 | 0.476 |
| RP1 | 0.596 | 0.466 | 0.654 | 0.779 | **0.945** | 0.476 | 0.504 | 0.522 | 0.368 | 0.502 | 0.538 |
| RP2 | 0.599 | 0.582 | 0.640 | 0.823 | **0.950** | 0.502 | 0.592 | 0.578 | 0.413 | 0.560 | 0.506 |
| AE1 | 0.434 | 0.636 | 0.476 | 0.424 | 0.473 | **0.958** | 0.603 | 0.577 | 0.466 | 0.643 | 0.527 |
| AE2 | 0.448 | 0.644 | 0.498 | 0.402 | 0.530 | **0.945** | 0.631 | 0.622 | 0.473 | 0.659 | 0.604 |
| AE3 | 0.524 | 0.630 | 0.548 | 0.428 | 0.463 | **0.936** | 0.583 | 0.523 | 0.459 | 0.532 | 0.554 |
| RT1 | 0.682 | 0.733 | 0.642 | 0.569 | 0.575 | 0.651 | **0.968** | 0.772 | 0.557 | 0.692 | 0.619 |
| RT2 | 0.586 | 0.641 | 0.535 | 0.464 | 0.548 | 0.590 | **0.972** | 0.787 | 0.625 | 0.694 | 0.628 |
| BE1 | 0.594 | 0.696 | 0.611 | 0.452 | 0.532 | 0.645 | 0.756 | **0.945** | 0.682 | 0.769 | 0.712 |
| BE2 | 0.622 | 0.654 | 0.634 | 0.477 | 0.576 | 0.628 | 0.790 | **0.972** | 0.673 | 0.759 | 0.673 |
| BE3 | 0.629 | 0.647 | 0.545 | 0.462 | 0.546 | 0.446 | 0.744 | **0.929** | 0.647 | 0.699 | 0.687 |
| EE1 | 0.431 | 0.612 | 0.522 | 0.295 | 0.400 | 0.483 | 0.611 | 0.630 | **0.932** | 0.634 | 0.552 |
| EE2 | 0.346 | 0.527 | 0.415 | 0.254 | 0.378 | 0.493 | 0.519 | 0.668 | **0.920** | 0.636 | 0.558 |
| EE3 | 0.463 | 0.527 | 0.463 | 0.317 | 0.368 | 0.390 | 0.566 | 0.658 | **0.927** | 0.594 | 0.510 |
| MS1 | 0.563 | 0.642 | 0.607 | 0.452 | 0.489 | 0.599 | 0.621 | 0.667 | 0.673 | **0.931** | 0.638 |
| MS2 | 0.624 | 0.619 | 0.607 | 0.520 | 0.526 | 0.603 | 0.701 | 0.756 | 0.611 | **0.967** | 0.675 |
| MS3 | 0.609 | 0.613 | 0.579 | 0.506 | 0.586 | 0.641 | 0.719 | 0.811 | 0.637 | **0.961** | 0.705 |
| RE1 | 0.650 | 0.451 | 0.595 | 0.452 | 0.500 | 0.520 | 0.608 | 0.714 | 0.563 | 0.683 | **0.963** |
| RE2 | 0.594 | 0.596 | 0.643 | 0.518 | 0.560 | 0.624 | 0.632 | 0.688 | 0.560 | 0.678 | **0.963** |

### 4.2.3 Structural Model Evaluation

The bootstrapping method was then used to determine the significance of path coefficients and to test the hypotheses. After that, structural model assessment is performed to evaluate the model's explanatory power and to test the research hypothesis by assessing the inner model. There were 5,000 bootstrap samples used in this study [28]. The significance threshold for a two-tailed test was set at $p<0.05$, and the crucial t-value was determined to be >1.98.

Based on the results, technical aspects exert a favorable and substantial impact on sustainable campus status. Table 6.0 demonstrates that technical aspects exhibit the strongest association compared to management aspects, with a route coefficient value of 2.447 and 5.032, respectively. In addition, the management aspect consists of organizational structure, energy policy, planning, audit, reporting, and awareness or education. It reveals that reporting is most supported in BIM Strategies to enhance energy efficiency toward a sustainable campus. While in technical aspects, which consist of retrofitting, building envelope, efficiency equipment, mechanical systems, and renewable energy, the most supported strategy is the mechanical systems element. According to the findings in Table 6.0, the path coefficients for Hypotheses 1 and Hypothesis 2 were all positive and significant at the 0.05 level, which indicates that these two hypotheses were valid and should be supported.

**Table 6 - Structural model evaluation**

| Hypothesis | Path Analysis | p-Value | t-Value | Decision |
|---|---|---|---|---|
| | **MANAGEMENT→ Sustainable Campus** | **0.01** | **2.447** | **Supported** |
| | Organizational → Management | **0.001** | 12.007 | Supported |
| | Energy Policy→ Management | **0.001** | 14.116 | Supported |
| | Planning → Management | **0.001** | 14.472 | Supported |
| | Audit → Management | **0.001** | 15.234 | Supported |
| | Reporting → Management | **0.001** | 17.416 | Supported |
| | Education/Awareness→ Management | **0.001** | 13.037 | Supported |
| **H2** | **TECHNICAL → Sustainable Campus** | **0.001** | **5.032** | **Supported** |
| | Retrofitting → Technical | **0.001** | 17.611 | Supported |
| | Building Envelope→ Technical | **0.001** | 22.363 | Supported |
| | Efficiency Equipments → Technical | **0.001** | 18.140 | Supported |
| | Mechanical Systems → Technical | **0.001** | 24.725 | Supported |
| | Renewable Energy→ Technical | **0.001** | 16.588 | Supported |

## 5. Conclusion

Overall, the results show that management and technical aspects in BIM strategies according to Energy Sustainability Elements have a positive impact on a sustainable campus, with path coefficients of 2.447 and 5.032, respectively. Furthermore, the findings have revealed that Hypothesis 1 and Hypothesis 2 were all positive and significant at the 0.05 level, indicating that these two hypotheses are valid and supported. It indicates that a combination of management aspects (organizational structure, energy policy, planning, auditing, reporting, and awareness or education) and technical aspects (retrofitting, building envelope, efficient equipment, mechanical systems, and renewable energy) in BIM strategies can drive the campus energy efficiency initiative based on the respondents from the AEC industry in Sabah.

This study can be used as a baseline framework and encourages all industry and campus stakeholders. The management, energy team, experts, engineers, architects, and contractors to apply the strategies of BIM according to Energy Sustainability Elements to create a sustainable campus and make Malaysia a green technology hub by 2030 (Ministry of Energy, Green Technology and Water in Malaysia, 2017), for which a Green Technology Master Plan (GTMP) was recently developed and launched, which includes various efforts to be undertaken in Malaysia between 2017 and 2030 in the area of energy efficiency.

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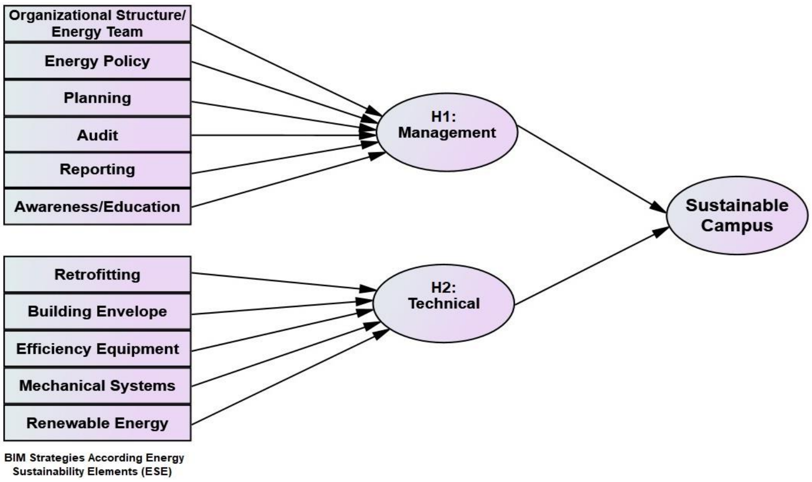
## Appendix A: Conceptual Framework For This Study




## Appendix B: Structural Relationship Between Building Information Modelling (BIM) Strategies in Energy Sustainability Elements Towards Sustainable Campus Using SMART PLS 3.0