

Barriers and Opportunities in Digitalizing Energy Management Systems in the Built Environment of Malaysian Public Universities

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Abstract

The digital transformation of energy systems in the built environment has emerged as a critical strategy to improve efficiency, sustainability, and operational resilience, particularly within institutional infrastructures such as public universities. Motivated by the increasing demand for smart energy solutions, this study investigates, for the first time to our knowledge, the barriers and progress related to the digitalization of energy management systems across Malaysian public universities. Despite global momentum, digital uptake in Malaysia's higher education sector remains slow, and research on institution-specific challenges is limited. This study aims to identify the key internal and external barriers that hinder energy-related digitalization efforts within university campuses, and assess the implementation progress across various digital verticals, particularly energy management and building automation. A structured survey was distributed to facility directors, energy managers, and sustainability officers at 13 public universities. Responses were quantitatively analyzed using ranking and scoring frameworks. The findings reveal that high costs, limited funding, and inadequate governmental incentives are the most pressing obstacles, highlighting a strong correlation between financial limitations and stalled progress. Energy management and building automation emerged as the most developed digital domains, while health and well-being monitoring lag significantly behind. This research contributes valuable insights for policymakers, energy solution providers, and institutional planners in aligning digitalization strategies with national sustainability objectives. It directly supports SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action) by advancing digital energy transformation in Malaysia's higher education sector.

Keywords

Digitalization, Built Environment, Internal Barriers, External Barriers, Public Universities

1. Introduction

The last COVID-19 has urged rapid and instant transition to digitalization in usual practices including in built environment sector [1] [2], which has significantly impacting energy consumption patterns. Since then, there has been a growing demand for the implementation of digital platform in the built environment sector in order to minimize the transmission [3], specifically from the perspectives of urban health strategies, risk assessment, transport, as well as building automation, control and management [4]. In fact, for building users, digitalization guarantees not only resource efficiency and service improvement but also significant energy savings through smarter systems and real-time monitoring. This makes energy-efficient digital solutions a highly relevant topic for discussion and a rewarding business area with growing demand in the built environment sector [5].

Despite a few case studies that have been made abroad [6]-[8], barriers to digitalization in built environment among public universities in Malaysia (IPTA) has not been well researched. An exploratory research methodology is hence to be utilized, comprising structured online survey conducted among the responsible personnel for their respective university's sustainability mission. The respondents were selected in their capacity of currently being the Director of Facility, Development, Sustainability and/or Built Environment Center, or Energy Manager from different IPTA in Malaysia. The participating universities in this survey are:

- 1) Universiti Sains Malaysia (USM)
- 2) Universiti Teknologi Malaysia (UTM)
- 3) Universiti Tun Hussein Onn Malaysia (UTHM)
- 4) Universiti Sains Islam Malaysia (USIM)
- 5) Universiti Putra Malaysia (UPM)
- 6) Universiti Malaysia Perlis (UNIMAP)
- 7) Universiti Teknikal Malaysia Melaka (UTeM)
- 8) Universiti Islam Antarabangsa Malaysia (IIUM)
- 9) Universiti Malaysia Kelantan (UMK)
- 10) Universiti Malaysia Pahang (UMP)
- 11) Universiti Teknologi MARA (UiTM)
- 12) Universiti Malaysia Sarawak (UNIMAS)
- 13) Universiti Utara Malaysia (UUM)

A total of 13 universities responded to the survey out of 20 targeted institutions, representing approximately two-thirds of Malaysia's public universities. While this constitutes a substantial proportion, it should be noted that Malaysia has 20 public universities in total. The responding institutions include both research-in-

tensive universities (e.g., Universiti Sains Malaysia, Universiti Teknologi Malaysia) and more recently established universities (e.g., Universiti Malaysia Kelantan, Universiti Malaysia Pahang). Thus, the sample covers a diversity of institutional types, geographic regions, and sizes, enhancing representativeness. Nonetheless, the non-response from some institutions introduces the possibility of response bias, as universities with more advanced sustainability and digitalization initiatives may have been more inclined to participate.

The aims of this study are to analyze the barriers to digitalization of the built environment from the perspective of public universities in Malaysia, while evaluating the progress level of these institutions in implementing digitalization within their campus infrastructure. For the first time to our knowledge, this research provides a nationwide assessment across multiple public universities, offering unique insights into both the challenges and advancements in campus digital transformation efforts.

This study has several limitations that should be acknowledged. First, the relatively small sample size (13 universities) limits the generalizability of the findings across all Malaysian public universities. Second, the reliance on self-reported survey data introduces potential biases related to respondents' perceptions, selective reporting, or optimism. Finally, the cross-sectional design provides only a snapshot of the current state of digitalization and barriers, without capturing longitudinal changes or causal relationships. Future research could address these limitations by employing larger and more representative samples, integrating objective performance data, and adopting longitudinal or mixed-method designs.

2. Methodology

2.1. Respondent Selection and Survey Design

A list of targeted respondents (**Table 1**) was prepared based on a desktop-search through the staff directory page of each IPTA, focusing on those accounted for facility management or university's sustainability initiatives. A total of 20 potential respondents were initially listed but only 13 of them volunteered to submit their responses. The link to questionnaires was sent out to each of them via their official email address, along with the definition of the term "built environment" and brief explanation on the context of digitalization around which this survey study should revolve. The term "Built Environment" itself refers to the man-made structures, features, and facilities viewed collectively as an environment in which people live and work [9].

Meanwhile, the context of DIGITALIZATION related to this study is briefly explained below:

- Use of the Internet of Things (IoT) solutions with technology devices (PC, tablets and smartphones) to fully automate daily operations and thus, enhancing products and services.
- Integration of Information Technology (IT) and Operational Technology (OT) to optimize asset inspections, monitoring and failure assessments while

storing all the data in the cloud.

- Utilization of Artificial Intelligence as the driving force to anticipate the future and hence, suggest the most effective strategies.

Table 1. List of respondents.

Respondents	*Department & IPTA	*Position	Education level
Respondent 1	Development & asset management office, USM	Director	MSc
Respondent 2	Asset management division (development office), UTM	Chairman	PhD
Respondent 3	Sustainability campus office, UTHM	Energy manager	PhD
Respondent 4	Development & facility management office, USIM	Director	BSc
Respondent 5	Development & asset management office, UPM	Energy manager	BSc
Respondent 6	Sustainability & energy management office, UNIMAP	Director	PhD
Respondent 7	Smart environment office, UTeM	Energy manager	PhD
Respondent 8	Occupational safety, health and built environment office, IIUM	Director	PhD
Respondent 9	Development office, UMK	Director	PhD
Respondent 10	Center for property management & development, UMP	Director	MSc
Respondent 11	UiTM green centre, UiTM	Director	PhD
Respondent 12	Development office, UNIMAS	Deputy director	BSc
Respondent 13	Development and maintenance department, UUM	Deputy director	BSc

*as in February 2023.

The questionnaires were set up using Google Form, which can be viewed via this link. They were properly crafted in the direction of accomplishing the main two objectives of this study. For that, the questions were grouped under two parts, e.g., Part A and Part B.

2.2. Part A: Barriers to Digitalization

The questions are in the form of five-point Likert scale [10], on which the respondents were asked to rate (from 1 to 5) on the potential barriers to digitalization in built environment, which was extracted from the previous studies that have been conducted [11]-[13]. The barriers were then categorized into internal and external ones [14] [15], before being ranked according to scores collected from the responses. The score assigned to each response is tabulated in **Table 2**.

Internal barriers:

- High cost for products and services in implementing digitalization.
- Lack of training related to the digitalization among the technical staff.
- Lack of environmental awareness among the shareholder/decision makers.
- Lack of research in local context on digitalization in built environment.
- Low commitment to green development by the organization.

External barriers:

- Lack of regulations and codes as well as enforcement by the local authority.
- Lack of subsidies and incentives from the government.
- Limited finance support (fund) for the up-front cost.
- Future risk and uncertainties upon implementing digitalization.

Table 2. Score for each response of questions under Part A.

Response	Score
Strongly agree	5
Agree	4
Neutral	3
Disagree	2
Strongly disagree	1

2.3. Part B: Progress Level Towards Digitalization

The questions as in **Table 3** were crafted in line with main business verticals comprising of energy management, building automation and control, space utilization monitoring, assets and facilities monitoring, building security, fire safety as well as occupant health and well-being. The score assigned to each response is tabulated in **Table 4**, in order to rank each vertical in terms of the overall progress level as well as each participating IPTA in terms of their progress level in implementing digitalization. The score scheme in **Table 4** is then revised to a new scheme as in **Table 5**, in order to rank the potential level of each participating IPTA towards implementing digitalization in built environment.

Table 3. Questions in assessing progress level towards digitalization.

Question code	Survey question
Q1 (B)	Does your organization currently implement, or plan to implement, digitalization for energy management?
Q2 (B)	Does your organization currently implement, or plan to implement, digitalization for building automation and control?
Q3 (B)	Does your organization currently implement, or plan to implement, digitalization for space utilization monitoring?
Q4 (B)	Does your organization currently implement, or plan to implement, digitalization for monitoring the condition of assets and facilities?
Q5 (B)	Does your organization currently implement, or plan to implement, digitalization for your building security?
Q6 (B)	Does your organization currently implement, or plan to implement, digitalization for your building fire safety?
Q7 (B)	Does your organization currently implement, or plan to implement, digitalization for monitoring the occupant health and well-being? (e.g.: temperature, indoor air quality, humidity)

Table 4. Score for each response of questions under Part B.

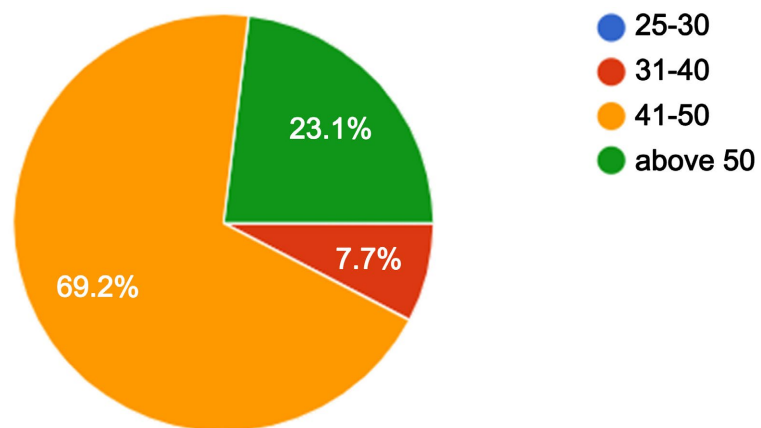
Response	Score
Significant implementation of digitalization	4
Some implementations of digitalization	3
Planning to implement digitalization	2
Not implementing digitalization	1
Not sure	-

Table 5. Revised score for each response of questions under Part B.

Response	Score
Planning to implement digitalization	4
Some implementations of digitalization	3
Significant implementation of digitalization	2
Not implementing digitalization	1
Not sure	-

3. Survey Results

From the demographic information obtained through the survey, large majority of respondents' age are between 41 and 50 years old, as illustrated in **Figure 1**. In terms of education level (see **Figure 2**), all respondents possess at least a Bachelor's degree in various fields, with more than half holding a PhD. This high level of academic qualification enhances the credibility and reliability of the survey findings, as it indicates that the respondents are not only knowledgeable but also likely to have a deeper understanding of institutional structures, technological frameworks, and strategic planning. Their academic background lends weight to their insights, making the responses more informed, reflective, and suitable for drawing meaningful conclusions about digitalization and energy management in the built environment.

**Figure 1.** Range of age among respondents.

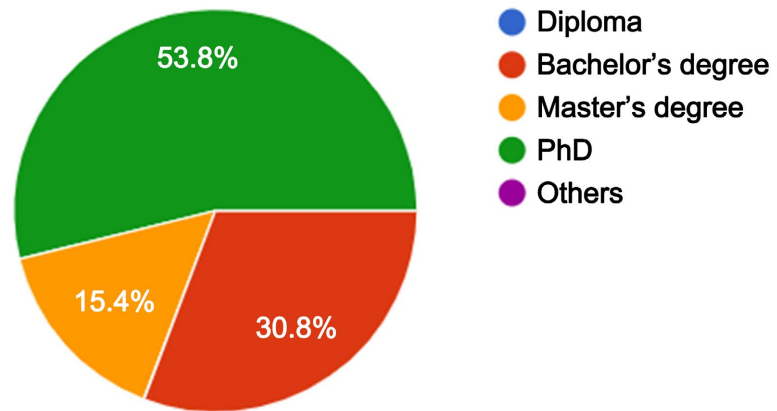


Figure 2. Education level of respondents.

3.1. Part A: Barriers to Digitalization

To further simplify the ranking process and analysis, each barrier has been assigned with a short keyword as listed in **Table 6**.

Table 6. Keyword for each barrier to digitalization.

Barriers to digitalization	Keyword
High cost for products and services in implementing digitalization	<i>cost</i>
Lack of training related to the digitalization among the technical staff	<i>training</i>
Lack of environmental awareness among the shareholders/decision makers	<i>awareness</i>
Lack of research in local context on digitalization in built environment	<i>research</i>
Low commitment to green development by the organization	<i>commitment</i>
Lack of regulations and codes as well as enforcement by the local authority	<i>regulations</i>
Lack of subsidies and incentives from the government	<i>incentives</i>
Limited finance support (fund) for the up-front cost	<i>financial</i>
Future risk and uncertainties upon implementing digitalization	<i>risk</i>
High cost for products and services in implementing digitalization	<i>cost</i>

Table 7. Ranking for internal barriers.

Response	Score	Ranking	Standard deviations
Cost	4.46	1	0.88
Awareness	3.92	2	0.64
Training	3.77	3	1.01
Commitment	3.62	4	1.12
Research	3.46	5	0.97
Overall mean	3.85		

The mean value for each barrier was calculated, with the highest mean indicating the top-ranked barrier. Among the internal barriers, the cost of products and

services stands out significantly above the others, as shown in **Table 7**. Notably, this finding aligns closely with the results for external barriers, where limited financial support emerges as the most prominent issue, as illustrated in **Table 8**.

Table 8. Ranking for external barriers.

Response	Score	Ranking	Standard deviations
Financial	4.38	1	0.87
Incentives	4.31	2	0.85
Regulations	3.69	3	0.75
Risk	3.62	4	0.77
Overall mean	4.00		

The overall mean value for internal and external barriers are also calculated and compared, as shown earlier in **Table 7** and **Table 8**, respectively. The comparison reveals that the mean value for external barriers is slightly higher than that of internal barriers. Additionally, all internal and external barriers were consolidated to form a comprehensive overall ranking, as shown in **Table 9**. Interestingly, the top three barriers are all associated with financial factors [16], with mean values exceeding 4.00 that is significantly higher than those of the other identified barriers.

Table 9. Overall ranking for both internal and external barriers.

Response	Score	Ranking	Standard deviations
Cost	4.46	1	0.88
Financial	4.38	2	0.87
Incentives	4.31	3	0.85
Awareness	3.92	4	0.64
Training	3.77	5	1.01
Regulations	3.69	6	0.75
Commitment	3.62	7	1.12
Risk	3.62	7	0.77
Research	3.46	9	0.97

The findings highlight that the most prominent barriers are financial in nature, including high upfront costs, limited funding, and insufficient government incentives. These results resonate strongly with ongoing national policy debates. In particular, Malaysia's Green Technology and Climate Change Corporation (MGTC) has introduced various grant schemes, such as the Low Carbon Cities Grant Program and related financial incentives, aimed at supporting energy efficiency and digital transformation initiatives. However, the survey responses suggest that awareness and accessibility of such programs remain uneven across public uni-

versities. Strengthening the alignment between institutional digitalization needs and existing governmental funding mechanisms, including streamlined access to MGTC support, could help alleviate these critical barriers. The results therefore emphasize not only institutional challenges but also opportunities for policymakers to enhance incentive structures and better target universities as key stakeholders in Malaysia's sustainability transition.

3.2. Part B: Progress Level in Implementing Digitalization

Again, to further simplify the ranking process and analysis, each question is assigned with a short keyword that represents main business verticals related to digitalization in built environment as listed in **Table 10**.

Table 10. Keywords representing business verticals

Survey questions	Business verticals
Does your organization currently implement, or plan to implement, digitalization for energy management?	<i>energy management</i>
Does your organization currently implement, or plan to implement, digitalization for building automation and control?	<i>building automation</i>
Does your organization currently implement, or plan to implement, digitalization for space utilization monitoring?	<i>space utilization</i>
Does your organization currently implement, or plan to implement, digitalization for monitoring the condition of assets and facilities?	<i>assets and facilities</i>
Does your organization currently implement, or plan to implement, digitalization for your building security?	<i>building security</i>
Does your organization currently implement, or plan to implement, digitalization for your building fire safety?	<i>fire safety</i>
Does your organization currently implement, or plan to implement, digitalization for monitoring the occupant health and well-being?	<i>health and well-being</i>

Table 11. Ranking for overall progress level.

Keywords	*Mean (maximum score = 4)	Standard deviations	Rank
Building automation	2.77	0.76	1
Energy management	2.62	0.96	2
Assets and facilities	2.27	0.65	3
Building security	2.25	0.87	4
Space utilization	2.18	0.87	5
Fire safety	2.08	0.79	6
Health and well-being	1.82	0.75	7

The mean value for each business vertical was calculated, with the highest mean

assigned the top rank. Among the listed verticals, building automation and control emerged as the highest-ranked, followed closely by energy management, as shown in **Table 11**. Conversely, digitalization related to occupant health and well-being showed the lowest level of implementation, likely due to its relatively recent emergence during the COVID-19 pandemic [9]. This is in contrast to the growing evidence supporting the positive impact of WELL Certification on building occupants, particularly in terms of workplace satisfaction, physical and mental health, overall well-being, and productivity [10].

Table 12. Ranking of IPTA in terms of progress level towards implementing digitalization.

Rank	IPTA	Mean	Standard deviations
1	UTeM	3.40	0.55
2	UUM	3.00	0.58
3	USIM	2.71	0.49
4	UiTM	2.57	0.79
5	IIUM	2.57	0.53
6	USM	2.57	0.79
7	UTHM	2.50	0.71
8	UNIMAP	2.14	0.90
9	UTM	2.14	0.38
10	UMP	2.00	0.82
11	UMK	1.67	0.52
12	UPM	1.57	0.79
13	UNIMAS	1.43	0.79

Table 13. Ranking of IPTA in terms of potential level towards implementing digitalization.

Rank	IPTA	Mean	Standard deviations
1	UTM	3.86	0.38
2	UTHM	3.50	0.71
3	USM	3.43	0.79
4	IIUM	3.43	0.53
5	USIM	3.29	0.49
6	UMK	3.00	1.55
7	UUM	3.00	0.58
8	UiTM	2.86	0.90
9	UMP	2.86	1.35
10	UNIMAP	2.71	1.25
11	UTeM	2.60	0.55
12	UPM	2.14	1.46
13	UNIMAS	1.71	1.25

In addition, each participating IPTA was ranked based on its current progress in implementing digitalization within the built environment, as presented in **Table 12**. UTeM demonstrated the most significant advancement in this area, which aligns with its recent achievement of receiving the Diamond Recognition from the Malaysian Green Technology and Climate Change Corporation (MGTC) at the Low Carbon City Award 2022 held in February 2023. Furthermore, using the revised scoring scheme outlined earlier in **Table 5**, each IPTA was also ranked according to its individual potential for digitalization implementation. This evaluation, shown in **Table 13**, offers valuable insights for service providers seeking to identify prospective clients among these institutions in the near future.

4. Conclusions

From the perspective of public universities in Malaysia, the most dominant barriers to digitalization in built environment is merely related to the monetary factor *i.e.*, high cost of products and services, limited fund and lack of subsidies and incentives from the government. Financial support and incentives offered by either the government or financial institutions are crucially needed to overcome those barriers [17]. Their roles cannot be understated by creating both the incentives and the financial resources necessary to make upgrading built environment feasible.

Among the main business verticals, building automation and energy management are the ones undergoing the highest progression involving digitalization work in public universities. Any service provider may think of a steadfast strategy in boosting the digitalization in health and well-being aspects since they appear to be the lowest progression in public universities, despite being worsened due to the pandemic [18].

Each university also possesses different progress in and oppositely, potential level towards deploying digitalization. The top 5 universities having the biggest potential are UTM, UTHM, USM, IIUM and USIM, which should be highly considered by any service provider in becoming their technology partner to expedite their digitalization mission.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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