Research in Management of Technology and Business Vol. 3 No. 1 (2022) 078–094

RMTB

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rmtb
e-ISSN : 2773-5044

A Foresight Study on the Adoption of Building Automation System in Malaysia

Alina Sumari[1] & Siti Aisyah Salim[1]*

[1]Department of Management and Technology, Faculty of Technology Management and Business,
Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rmtb.2022.03.01.007
Received 31 March 2022; Accepted 30 April 2022; Available online 25 June 2022

Abstract: Building automation system (BAS) is a system that manages the electrical and mechanical systems in a building. The usage of electrical energy in most countries goes up to 40 percent which is equivalent to 39 percent of process related carbon dioxide emissions. Malaysia is one of the countries that have high consumption of electricity contributed from different sectors. The discussion on the adoption and practicality of BAS technology is still lacking in the context of Malaysia. Thus, the aim of this study is to identify the key drivers of the BAS adoption and to determine the future trends of BAS adoption in Malaysia. In this study, a mixed method approach was used which included STEEPV and a quantitative study. The quantitative study is conducted by distributing the questionnaires to the green building developers in Malaysia. Impact uncertainty is analysed based on the key drivers and issues from the qualitative and quantitative methods. Ten merged key drivers and issues had been identified from the STEEPV method. The impact-uncertainty analysis approach had been used to identify the future trends of BAS adoption. About 50 questionnaires had been distributed with response rate 64.00%. This study found that resources of work efficiency and effectiveness to reduce energy consumptions had the highest impact and uncertainty. Four scenarios were proposed at the end of the study. The four scenarios were sustainable development of BAS, stagnant or sluggish technology, achieved green certification and improved comfort and experience.

Keywords: Building Automation System, Adoption, Foresight

1. Introduction

Over the past few years, buildings have evolved into highly monitored data sources, with thousands of sensors, actuators, and configuration data (Stimmel, 2015). As the building industry changes, the growth of new technologies such as cloud computing, Internet of Things (IoT), sensing technology in diverse fields has driven the introduction of automation (Verma *et al.*, 2016). The word automation refers to techniques of electronics, informative and telecommunications that are applied in systems to

**Corresponding author: aisyahs@uthm.edu.my*

make it smarter (Jumrukovska, 2019). Automation has been used in managing the infrastructure of building in many organizations (Huang *et al.*, 2017). For automation in a building, IoT concepts and technology must be implemented (Atkinson, 2017). The IoT has already found its way into a variety of applications, including building automation systems (BAS) (Spinsante *et al.*, 2017). Building automation equipped with IoT technology enables buildings to collect and process data without using people's time, as well as allowing users to alter the settings simply using the Internet. IoT integration is performed by adding Internet-capability to sensors and actuators, either by direct network connection or by interfacing particular gateways for data collecting and control (Kang *et al.*, 2017; Supramaniam *et al.*, 2017). BAS is becoming increasingly important in a wide range of sectors, especially when green buildings and smart buildings have been the popular choice. BAS is a network of controlled devices that monitor and govern the building's systems including HVAC, lighting, security system, ventilation or air purification system, air handlers, sterilizing or sanitizing system and mechanical system. The implementation of BAS in a building helps organizations to monitor the energy consumption with insufficient control functions and high dependence on human factors (Chin & Lin, 2015). Thus, BAS helps information to be delivered to various systems and it also enables actions to be automated at any time (Wong, 2020).

According to the International Energy Agency, the electric consumption will keep growing up to 53% of consumption in 2030 and most of these consumptions are coming from developing countries (Visconti *et al.*, 2019). Malaysia is one of the countries that have high consumption of electricity contributed from different sectors (Yudelson, 2020). Electricity gives satisfaction and diversity of functions and energy services such as heating, ventilation, air conditioning (HVAC), lighting and other electrical applications (Jumrukovska, 2019).

The recent development of BAS technology provides the opportunity to develop adequate environments in a building. This is because BAS is designed to save energy and minimize the emission of harmful substances throughout its life cycle (Yudelson, 2020). BAS technology also helps to promote sustainability for built a good atmosphere and to make the building more environmentally friendly (Siva *et al.*, 2017). According to Tan (2009), BAS can promote energy efficiency and it is one of the criteria that the building must have to be awarded green certification. Energy efficiency also means diminishing the energy consumption to an acceptable level of comfort, good air quality and others.

Furthermore, BAS refers to automatic centralized control in which a network of intelligent microprocessor-based controllers is used to monitor and control facilities, technical systems, and services. The solution offered by IoT allows to collect mass data from wearable devices, sensors and actuators to execute meaningful actions (Stimmel, 2015).

Malaysia is one of the developing countries that has high electricity consumption (Allen *et al.*, 2017). As such, it has increased the carbon dioxide (CO_2) emissions (Amirrudin *et al.*, 2020). According to the British Petroleum Statistical Review of World Energy (2019), the emission of carbon dioxide in Malaysia has increased 2% which is 250.3 million tons in 2019 rather than 241.6 million tons in 2017. The main sources of the emissions were energy which is electricity consumption of the buildings (Anderson & Rainie, 2018). Due to this scenario, the Malaysian government has committed towards green recovery, advocating a sustainable development agenda in the 2021 Budget. Nevertheless, green building is not a common topic in Malaysia. According to the World Green Building Council, green building is designed to reduce and influence a positive impact of the climate and natural environment. However, there is a lack of awareness of green building among Malaysians. In addition, Building Automation System (BAS) technology offers the creation of a Green Building Environment (GBE) (Infosystems, 2017). Recently, there are lots of natural disasters that happen including floods, landslides and severe haze. The natural disaster can result in significant building and facilities damages. In Malaysia for example the recent flood has caused an electrical substation in Shah Alam to explode after heavy floods.

The development of BAS holds huge potential as it provides significant impact towards monitoring and controlling of a building (Luo *et al.*, 2021). According to Behar (2017), building monitoring systems will be more intelligent if the wireless system is applied to monitoring and controlling the devices. The use of BAS also could also adjust the facilities that they need (Visconti, 2019). Few benefits of BAS discussed in previous research include that it can reduce the energy consumption about 5% up to 35% and also reduce the carbon dioxide emissions (Visconti, 2019). The BAS will be more efficient than the traditional system by more than 60% if the system runs at the optimum speed (Atkinson, 2017). Thus, BAS will enable smarter and more sustainable living to the users as it can monitor the devices automatically suitable for environmental conditions (Simmonds & Bhattacherjee, 2015). Hence, the BAS can save building energy and costs in contrast to manually controlling buildings (Azliana *et al.*, 2019). BAS also could keep informed of system functioning, device breakdowns and can communicate with building administrators through emails and text (Ghosh *et al.*, 2015).

Though there are many benefits of BAS discussed, it is undeniable that any advanced technology will have certain limitations in the beginning of its development (Anderson & Rainie, 2018). According to a study by the International Standards (2010), it is feasible to measure the level of risk for a BAS and give necessities that need to be met such as to accomplish the desired goal of safety and availability. BAS failures can also be caused by internal (reliability) and external (security) factors, as well as software flaws and cyber-attacks on vulnerabilities (Kharchenko *et al.*, 2017). Next, the heterogeneous mix of device networks for allowed monitoring and control can turn into exposed to weakest links (Stamatescu *et al.*, 2020). For instance, it allows hijacking of basic light switches that enter temperature set-points at the room level. Additionally, the barriers to implementing new technology because the building owners have lack of knowledge and low awareness of the synergistic advantages of integrating different technologies as it a platform for abstracting, modeling and validating new technologies consequently restrains their adoption (Jia *et al.*, 2018). BAS may also be used as a fire and flood early warning system, as well as a theft detection system with cameras that can be viewed remotely via the Internet using a device that can monitor and control any electrical equipment in the building (Lim *et al.*, 2016). When it detects an emergency, such as a fire or a flood, it switches off any equipment that could threaten the occupants.

Despite many benefits BAS could provide, the adoption of this technology is still very rare in Malaysia thus it is expected to grow over the forecast period as the Industrial Revolution 4.0 initiative. Further, the limitation of the information and previous studies related to this study have also motivated me to conduct this research. Therefore, the purpose of this research is to determine the key drivers that lead to BAS adoption in Malaysia as well as to explore future trends of BAS technology in Malaysia.

Therefore, to achieve the research objectives the key drivers that lead to building automation system adoption in Malaysia are determine. Consequently, the future trend of building automation system in Malaysia is identified.

The purpose of this study is to determine key drives that influence the BAS adoption in Malaysia. It also will determine the future trends of smart building technology. This foresight study will be carried out keeping in view the timeframe of 10 years in future or in other words from the year 2021 to the year 2031. The present research focuses on each resource or information related to the trend of BAS adoption in Malaysia. All relevant data and information are gathered from a variety of sources, including journals, conference proceedings, government-related papers, the Internet, non-governmental organizations, YouTube, and various types of research materials relating to BAS adoption. The target respondent of this research would be the selected and covered among the green building developers in Malaysia. Questionnaires will be distributed to the advocates for the data collection analysis.

This research will be conducted to explore the drives to adopt BAS and the future trend of BAS adoption in Malaysia. This future study may help the organization to reduce energy consumption in a building by around 5% to35% thus it will lead to financial savings as well as a much more efficient and effective approach to meeting green goals (Azliana *et al.*, 2019). Furthermore, this research will help an organization and communities in Malaysia to use BAS technology while increasing the knowledge. Moreover, this research will provide the benefits to future researchers as this study provides evidence of the uncertainty of the BAS adoption in Malaysia. Therefore, this study helps Malaysians to be more familiar with this technology and build the country's image.

2. Literature Review

2.1 Building Automation System (BAS) Technology

BAS can be defined as a software that executes data and constructs automatic adjustments to building performance (Behar *et al.*, 2017). According to the University of New Hampshires, BAS can be defined as preserving the building's atmosphere within a specific range and collecting data to record the device's performance. Thus, BAS is a system that combines hardware and software that is linked to heating, venting and air conditioning systems (HVAC), lighting, security and other systems to transmit on a single platform. Additionally, BAS also helps in detecting problems and faults because it has access to a full range of building data (Verma *et al.*, 2016). For instance, BAS can trace temperature data which is important for appropriate climate control and increase people's comfort. BAS also can use sensors to decrease the air quality issues but still environmentally-friendly. BAS can provide crucial information on the functional performance of a building besides improving the safety and comfort of the people (Jumrukovska, 2019). According to Bolarinwa (2015), BAS is a network of microprocessor based wired or wireless controllers connected to diverse systems in a building to better manage the equipment and optimise an organisation energy spend provide access to information on equipment performance and utility metering and gives users the ability to easily schedule equipment and control it at a more granular level.

According to Carnevale (1992), there are four key technologies of BAS. First, the heating, ventilation and air condition (HVAC). BAS technology helps the devices in decreasing the energy consumption in uninhabited building zones, notice and identify faults and minimise HVAC usage. Second, smart lighting that incorporates daylighting and dimming functions to eliminate over-lit spaces. Third, automated system optimization (ASO). It functions as a device to collect and identify building systems operational and energy performance data for making changes in operations. Lastly, distributed energy resources (DER). Its function is to generate energy and storage systems placed at or near the point of use.

2.2 The Advantages of Building Automation System (BAS) Technology

BAS can enhance the building's various systems control including heating, ventilation and air-conditioning (HVAC), electrical, security and so on (Jumrukovska, 2019). These control systems are customised for each situation and range in complexity depending on the structure and objective (Chin & Lin, 2015). BAS is used in a lot of green buildings because it has a lot of advantages in the future (BigRentz, 2021). The demand for energy-efficient facilities with strengthened security systems has boosted the BAS market's growth (Gan, 2021). Energy-efficient is one of the biggest impacts of BAS as it can promote energy savings about 30% to 50% in a building (Derek & Clements-Croome, 1997). Therefore, due to the energy saving, the building also can decrease the total emission of carbon dioxide to the atmosphere that will lead to the green buildings (Daniel, 2016). Moreover, BAS is designed for continuous energy management for the accomplishment of the energy and cost savings (Etikan *et al.*, 2016). Other than that, BAS requirement for cabling is reduced and it lowers the installation and operational expenses also (Voigt & Osterlind, 2008). Consequently, the BAS may save building energy and costs in contrast to manually controlling buildings (Azliana et al., 2019). Therefore, it is capable of handling multiple devices efficiently and reduces the energy wastage due to human laziness. Furthermore, as the system can monitor automatically based on the sensor's detection, it can enhance the user experience by productivity enhancement, reduce costs and mitigate physical and cybersecurity risks (Fernandez-Carames & Fraga-Lamas, 2019). This is because the user will get better comfort, space utilisation and customised lighting to meet people preferences (Gan, 2021). Thus, BAS could save time and easier as it keeps informed of system functioning, device breakdowns and can communicate with building administrators through emails and text (Ghosh *et al.*, 2015). BAS also functions as a fire and flood early warning system, as well as a theft detection system with cameras that can be monitored remotely over the Internet using devices that can monitor and operate any electrical equipment in the building (Lim *et al.*, 2016). It turns down any equipment that could endanger the occupants when it detects an emergency such as fire and flood.

2.3 The Challenges of Building Automation System (BAS) Technology

Few challenges in using BAS as it is a new emerging technology in the market (GlobeNewswire, 2020). The challenge is security issues for system design and the integration of security subsystems, which significantly tightens security requirements to the protocol of a network control system, and weaknesses in the system design according to hardware and software components (Minchev *et al.*, 2013). BAS failures can be caused by intra (reliability) reasons and external (security) reasons including software faults and attacks on vulnerabilities (Kharchenko *et al.*, 2017).

Moreover, the absence in the development of mini scale self-controlling intelligent systems, necessity of infrastructure modifications and the flexibility limitation in existing installations are the major barriers for using BAS in general residential applications and existing buildings (BAS can enhance the building's various systems control including heating, ventilation and air-conditioning (HVAC), electrical, security and so on (Jumrukovska, 2019). These control systems are customised for each situation and range in complexity depending on the structure and objective (Ghosh *et al.*, 2015). BAS is used in a lot of green buildings because it has a lot of advantages in the future (BigRentz, 2021). The demand for energy-efficient facilities with strengthened security systems has boosted the BAS market's growth (Gan, 2021). Energy-efficient is one of the biggest impacts of BAS as it can promote energy savings about 30% to 50% in a building (Huang *et al.*, 2017). Therefore, due to the energy saving, the building also can decrease the total emission of carbon dioxide to the atmosphere that will lead to the green buildings (Jia *et al.*, 2018). Moreover, BAS is designed for continuous energy management for the accomplishment of the energy and cost savings (Jumrukovska, 2019). Other than that, BAS requirement for cabling is reduced and it lowers the installation and operational expenses also (Voigt & Osterlind, 2008). Consequently, the BAS may save building energy and costs in contrast to manually controlling buildings (Azliana et al., 2019). Therefore, it is capable of handling multiple devices efficiently and reduces the energy wastage due to human laziness. Furthermore, as the system can monitor automatically based on the sensor's detection, it can enhance the user experience by productivity enhancement, reduce costs and mitigate physical and cybersecurity risks (Kang, 2017). This is because the user will get better comfort, space utilisation and customised lighting to meet people preferences (Kharchenko, 2017). Thus, BAS could save time and easier as it keeps informed of system functioning, device breakdowns and can communicate with building administrators through emails and text (Ghosh *et al.*, 2015). BAS also functions as a fire and flood early warning system, as well as a theft detection system with cameras that can be monitored remotely over the Internet using devices that can monitor and operate any electrical equipment in the building (Lim *et al.*, 2016). It turns down any equipment that could endanger the occupants when it detects an emergency such as fire and flood (Lim *et al.*, 2016). From this scenario, it show the building owners have lack of knowledge and awareness on the synergistic advantages of integrating different technologies as it a platform for abstracting, modelling and validating new technologies consequently restrains their adoption (Jia *et al.*, 2018). Furthermore, the BAS challenge is uncalibrated sensors showing incorrect readings (Liu & Sheaffer, 2018). As sensors get old, some will lose their accuracy if not calibrated regularly. It is standard industry convention for maintenance contractors to calibrate sensors annually. If a sensor is showing an incorrect reading, if it is too high or too low, it may run equipment harder or longer than required.

2.4 Identification of Issues and Drivers

The STEEPV analysis is used to determine the major drivers and issues pertaining to the adoption of BAS in Malaysia. The issues and key drivers are categorised into six groups: social, technological, economic, environmental, political, and values. This will provide a clear image of the research's issues and key drivers. Social factors are related to the development of society including many factors. For instance, lifestyle, values, demographics, and religion. Through the identification of social factors helps in determining the future trend of BAS adoption in Malaysia. Thus, Technological factors are related to technological progress, pace of diffusion of innovations, problems and risks. Through the identification of technological factors helps in determining the future trend of BAS in Malaysia. Moreover, environmental factors are related to sustainability of the environment and climate change while implementing that involves the ecosystem factors which include water, soil, wind, and energy. Through the identification of environmental factors helps in determining the future trend of BAS adoption in Malaysia. Then, economic factors are related to the level distribution of economic growth, industrial structure, competition and competitiveness, markets and financial issues. Through the identification of economic factors helps in determining the future trend of BAS adoption in Malaysia. Next, political factors related to political development will highly influence individuals and organisations for example government's involvement and acceptance. Through the identification of social political factors helps in determining the future trend of BAS adoption in Malaysia. Furthermore, Value factor is related to positive elements instilled such as attitudes to working life and culture. Through the identification of value factors helps in determining the future trend of BAS adoption in Malaysia.

2.5 Merging Issues and Drivers

Change in issues and drivers identified from different sources such as journals, government related articles, the Internet and non-governmental organizations reports on BAS technology and categorizing it into social, technological, environmental, economic, political, and values. Table 1 shows all the ten key terms of issues and drivers derived from STEEPV analysis. These ten key terms were merged from a total 42 issues and drivers related to BAS technology. After the merging of key terms of issues and drivers which will be included in the questionnaires for the purpose of collecting data.

Table 1: Key Terms with Merged Issues and Drivers

No.	Issues and Drivers
1.	Advanced in living standard
2.	Safety and health
3.	Technology advancement
4.	Resource efficiency
5.	Saves time and costs
6.	Reducing environmental impact
7.	Reduced energy consumptions
8.	Government policies
9.	Security
10.	System faulty

3. Research Methodology

3.1 Research Design

In this research, both qualitative and quantitative approaches have been adopted to analyze and interpret data. The quantitative approach is more preferred by academics due to its features and strength (Daniel, 2016). This research, adopting questionnaires in order to collect the data. The questionnaires will be used to collect the data from the green building developers in Malaysia. The respondent data helps to explore information about the future possibilities to meet the needs as well as opportunities for the future. Thus, in the qualitative method, a foresight analysis approach is STEEPV. There are several important needs and issues that could affect the future usage of BAS.

3.2 Population and Sampling

A research population is a large group of people or items that are subject to the scientific study. It is also called a well-defined category of persons or objects considered to have comparable characteristics. According to Allen (2017), the population is made up of all the aims or events of a particular sort about which researchers want to learn more. A population is a set of instances or members of a group to whom the research is applied (Population of Cities in Malaysia, 2019). This research focuses on using BAS in Malaysia thus the target population is green building developers in Malaysia. This research is based on purposive sampling. Purposive sampling refers to the judgement sampling in which researchers deliberately choose the participants due to characteristics or quality that the participant possesses (Etikan *et al*., 2016). Sampling is the process of selecting and matching the number of units of the population. Sampling will be used in selecting respondents. This study has set 50 questionnaire samples.

3.3 Research Instrument

Research instrument is a set of questions used to collect data from respondents. A questionnaire, observation, and reading are among the research instruments. For the current study, the researcher must select a valid and reliable instrument. Questionnaire is chosen to use in this research because the data obtained with questionnaires was efficiently and easily quantified. The questionnaire involves 4 sections which are demographic (Section A), importance of BAS adoption in Malaysia (Section B), impact and uncertainty of BAS adoption in Malaysia (Section C, and Section D).

3.4 Data Collection

The data collection of this research is composed of secondary data and primary data collection. The primary data are collected by questionnaires. The questionnaire is given to the green building developers in Malaysia. While for secondary data, it will be collected through the analysis from several sources such as journals, articles, magazines, conference papers, websites, and thesis. This research is based on secondary data collection as the resource to support primary data. Thus, the primary and secondary data are used mutually for highest efficiency (Tran & Khuc, 2021). For instance, if the secondary data is inherited and provides a foundation, primary data will add newness, update and correctness.

3.5 Data Analysis

All collected data obtained is arranged into a systematic and easy to understand. Data analysis was carried out in order to identify the research findings and determine whether the research will achieve the research objectives. The descriptive analysis method and correlation analysis will be used to analyse the data collected from the primary sources, which was a questionnaire.

(a) Descriptive analysis

Descriptive analysis is used to see percentage and average mean value and frequency. In this study, the researcher will use descriptive analysis to figure out how to get population data from a sample. Statistical analysis method that was used to analyse the data for this research uses the SPSS software. It's a tool that gives users a variety of options for quickly examining data and putting scientific hypotheses to the test. Furthermore, the research can make clarifications on the basic results and data information for the research using percentage and mean.

(b) Impact-uncertainty analysis

The result of the questionnaire survey will be assessed using Statistical Package for the Social Sciences (SPSS). SPSS is one of the software applications that allow researchers to do statistical analysis, text analysis, integration with big data and others. This software may help researchers to collect key drivers that are evaluated by respondents of the survey. The key drivers listed will be placed and tested in impact-uncertainty analysis. The main drivers for the impact-uncertainty analysis are the variables with the highest impact and uncertainty.

(c) Future scenario analysis

Creating a scenario is intended to define potential consequences such as the future issues, trends, events, strategy and future-related development. The scenario analysis of the BAS adoption in Malaysia can be considered using both positive and negative implications.

4. Results and Discussion

4.1 Reliability Test

In a genuine study, a reliability test was performed to ensure the reliability of the research. According to Amirrudin (2020), the consistency of the measurement is implied by reliability, whereas inconsistency and imprecision are implied by lack of dependability, both of which are equated with measurement error. To analyze the internal consistency of each scale item for each primary construct, the Cronbach's Alpha coefficient was used to test for reliability for all elements on the questionnaire. The rule of thumb for calculating Cronbach's Alpha and determining reliability is shown in Table 2.

Table 2: Cronbach's alpha classification

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

The reliability test is a method of determining the internal consistency of a questionnaire (Bolarinwa, 2015). Cronbach's alpha, which may be used for three, four, or five-point likert scale items to test internal consistency, is the most commonly preferred, according to Table 2. Cronbach's Alpha is more interested in ranges from 0 to 1, which indicate low to extremely high internal consistency. To examine the inter-item consistency for measurement items in a construct, the Cronbach's alpha coefficient must be greater than 0.6. Hence, Cronbach's alpha is less than 0.6, the question's development potential is unclear, and there is repetition. In order for the instrument to be reliable, the question that is not at a suitable level should be rearranged or deleted.

(a) Reliability for pilot test

Table 3: Result of pilot test

Part	Drivers	Cronbach's Alpha	No of Items
B	Importance	0.837	10
C	Impact	0.930	10
D	Uncertainty	0.939	10

Based on the Table 3 above, Part B's Cronbach's alpha was 0.837, indicating that the research was a good level of reliability. Furthermore, the value of Cronbach's alpha for Part C was 0.930, indicating that the research had an excellent level of reliability. Finally, Cronbach's Alpha score for Part D was 0.939, indicating that it was on par with parts B and C, demonstrating that the research was of excellent reliability.

(b) Reliability for actual test

Table 4: Result for actual test

Part	Drivers	Cronbach's Alpha	No. Item
B	Importance	0.896	10
C	Impact	0.923	10

D	Uncertainty	0.921	10

Based on the Table 4 above, it shows the value of all Cronbach's alpha for all variables above the acceptance level which is more than 0.7. The results for importance, impact and uncertainty are 0.896, 0.923 and 0.921 respectively. The value of Cronbach's alpha should be above 0.7 or a minimum acceptable level of reliability would be 0.7. Based on the result, it shows each of the variables has a reliable value based on Cronbach's alpha.

4.2 Descriptive Analysis (Demographic)

Table 5 reports demographic analysis of respondents. Majority of respondents were male as compared to female respondents. Most of the respondents were between 26-30 years. Almost more than half of the respondents were Malay and most of the respondents have less than 5 years working experience. In regard to knowledge about BAS technology, the majority of them are familiar with the technology.

Table 5: Demographic Analysis

	Frequency (f)	Percentage (%)
Gender		
Male	20	62.5
Female	12	37.5
Total	32	100
Age		
21-25 years	8	25.0
26-30 years	18	56.3
31-35 years	5	15.6
36-40 years	1	3.1
41 years and above	0	0.0
Total	32	100
Race		
Malay	20	62.5
Chinese	12	37.5
Indian	0	0.0
Others	0	0.0
Total	32	100
Working Experience		
Less than 5 years	17	53.1
6 years-10 years	15	4609
11 years-15 years	0	0.0
16 years and above	0	0.0
Total	32	100
Knowledge about Building Automation System (BAS)		
Yes	28	87.5
No	4	12.5
Total	32	100

4.3 Analysis of Drivers based on its Importance

Based on Table 6, drivers 4 and 6, which are "*resource work efficiency*" and "*reducing environmental impact*" scored the highest mean (4.6875) indicates most of the respondents agreed the importance of BAS adoption can increase resource work efficiency and help to reduce energy consumptions. The lowest mean represented by the driver 9, "*security*" (3.4063). It shows respondents tend to claim that BAS leads users to experience security problems. Perhaps, there are many other factors that can trigger BAS adoption in Malaysia.

Table 6: Means of drivers on importance

No.	Issues and Drivers	Mean
1.	Advanced in living standard	4.5313
2.	Safety and health	4.6250
3.	Technology advancement	4.6563
4.	Resource work efficiency	4.6875
5.	Saves time and costs	4.5938
6.	Reducing environmental impact	4.6875
7.	Reduced energy consumptions	4.6250
8.	Government policies	4.6250
9.	Security	3.4063
10.	System faulty	3.5625

4.4 Analysis of Drivers based on its Impact

From Table 7, the highest mean that related to driver 4, "*resource work efficiency*" (4.7188) while drivers 3 and 7, "*technology advancement*" and "*reduced energy consumptions*" (4.6563) are the second and third highest. Therefore, more respondents agreed that resource work efficiency, technology advancement and reduced energy consumption have impacted on BAS adoption in Malaysia. The lowest mean is driver 10, which is "*system faulty*" (3.6250).

Table 7: Means of drivers on level of impact

No.	Issues and Drivers	Mean
1.	Advanced in living standard	4.5938
2.	Safety and health	4.5313
3.	Technology advancement	4.6563
4.	Resource work efficiency	4.7188
5.	Saves time and costs	4.5625
6.	Reducing environmental impact	4.5938
7.	Reduced energy consumptions	4.6563
8.	Government policies	4.5625
9.	Security	3.6875
10.	System faulty	3.6250

4.5 Analysis of Drivers based on its Uncertainty

Based on Table 8, all drivers have mean averages above 4.00 except for drivers 9 and 10, "*security*" and "*system faulty*" (3.7813, 3.8125). Drivers 7 and 8, "*reduced energy consumptions*" and "*government policies*" scored the highest mean (4.6875). The lowest mean score was 3.7813, for the driver 9, "security".

Table 8: Means of drivers on level of uncertainty

No.	Issues and Drivers	Mean
1.	Advanced in living standard	4.4688
2.	Safety and health	4.4688

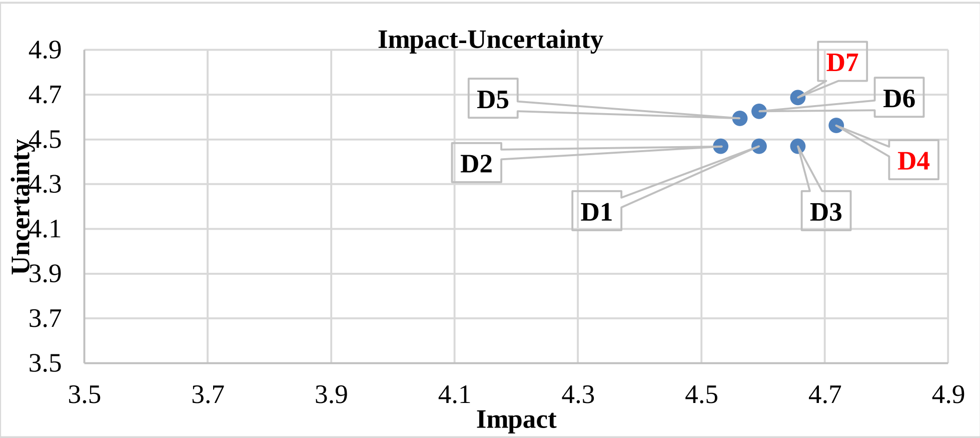
3.	Technology advancement	4.4688
4.	Resource work efficiency	4.5625
5.	Saves time and costs	4.5938
6.	Reducing environmental impact	4.6250
7.	Reduced energy consumptions	4.6875
8.	Government policies	4.6875
9.	Security	3.7813
10.	System faulty	3.8125

4.6 Impact-Uncertainty Analysis

The process for analyzing the impact uncertainty was done by plotting the mean of impact and uncertainty variables in a graph. Two drivers with the highest mean value of variables impact and uncertainty will be used for determining the future scenario. The mean of impact and uncertainty variables are illustrated in Table 9. Hence, all the data have been plotted as in Figure 4.1 and two drivers were used in generating the future scenario. The highest plot in the graph will be picked as the main two drivers.

Table 9: Mean of the 10 leading drivers on level of impact and uncertainty

No.	Issues and Drivers	Mean	
		Impact	Uncertainty
1.	Advanced in living standard	4.5938	4.4688
2.	Safety and health	4.5313	4.4688
3.	Technology advancement	4.6563	4.4688
4.	Resource work efficiency	4.7188	4.5625
5.	Saves time and costs	4.5625	4.5938
6.	Reducing environmental impact	4.5938	4.6250
7.	Reduced energy consumptions	4.6563	4.6875
8.	Government policies	4.5625	4.6875
9.	Security	3.6875	3.7813
10.	System faulty	3.6250	3.8125

Figure 

1: Impact-uncertainty analysis

As illustrated in Figure 1, top two drivers were identified which have the highest impact and uncertainty for the future trends of BAS adoption in Malaysia. Resource work efficiency (D4) has the highest impact while reduced energy consumptions (D7) has the highest uncertainty. These two drivers

(D4, D7) were used to build a scenario analysis in exploring the future trends of BAS adoption in Malaysia.

4.7 Discussion

(a) The key drives that lead to building automation system adoption in Malaysia

This study has set two research objectives. The first objective of this study is to determine the key drivers that lead to smart BAS adoption in Malaysia. The STEEPV analysis was used to achieve this objective. It is crucial to identify the issue and drivers of smart BAS adoption in Malaysia which may contribute to the potential users, management of the building and green building developers. The issues and drivers will determine the usage of smart BAS in Malaysia in the future. According to STEEPV analysis, the most influential factor for BAS technology adoption in Malaysia is the technological element, which is followed by value, economic, environmental, political and social factors.

(b) The future trend of building automation system adoption in Malaysia

The second objective of this research is to study the future trend of BAS adoption in Malaysia. The aim is to discover the trends that will drive future developments, as well as the future environment and market for BAS adoption in Malaysia. The trend is accomplished by using the top two drivers from the impact-uncertainty analysis to generate scenario analysis for four different alternative scenarios. The selected top two drivers have been discussed in the following section. It is discussed how uncertain future developments will be and what impact this will have on BAS adoption in Malaysia. In comparison to the other drivers, the top two selected drivers had the greatest impact and uncertainty.

The resource of efficiency has the highest impact and being the most uncertain driver compared to the others (4.7188, 4.5625). According to Luo *et al.* (2021), BAS technology is capable of providing efficient technology and infrastructure providing services to support and improve experiences. The private and government sector must consider the BAS adoption in Malaysia in the future. The implementation of standardization may help to increase the adoption of BAS in Malaysia. According to Liu & Sheaffer (2018), proactive measures taken by government organizations for the implementations of standards such as ISO 50001 (energy management-system standard) in the building sector, have the potential to stimulate the integration of BAS.

The second-highest driver is reduced energy consumption. The mean of the drivers is (4.6563, 4.6875) out of 5.000 in impact and uncertainty respectively. The operational efficiencies arising from the conservation of electric energy are outcomes of the system (Simmonds & Bhattacherjee, 2015). According to Minchev *et al.* (2020), energy-efficient is one of the biggest impacts of BAS as it can promote energy savings of about 30% to 50% in a building. This action may have a good impact on the building management specially to utilize the technical and management skills for achieving the target and developing the best performance in the esteemed organization. Developing this technology will bring an impact to the environment of Malaysia. It will also increase the quality level of the air thus giving a good impact towards the organization performance. According to Simmonds & Bhattacherjee (2015), implementations of BAS are expected to facilitate a more secure environment to building operations in terms of comfortable and productive performance.

These scenarios provide insight into four various possibilities that will occur in the next 5 to 10 years, from 2021 to 2031. Figure 2 presents the analysis of the four alternative scenarios. The scenarios will be addressed in order to determine the potential consequences of the predicted future trend of BAS adoption in Malaysia. Figure 2 illustrates four probable future scenarios for the BAS adoption in Malaysia.

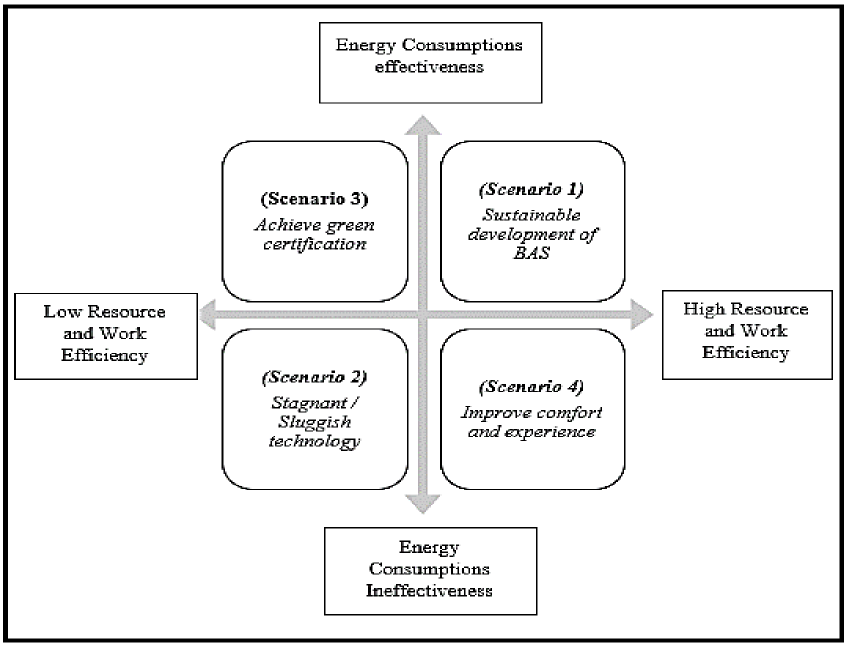


Figure 2: Four alternative scenario

The first scenario occurs when there is an effective energy consumption and high resource and work efficiency. This is the best scenario to achieve since it influences the adoption of BAS in Malaysia thus plays a role as a catalyst to sustainable development of BAS. Sustainable development of BAS refers to a situation where BAS technology can improve the experience of people in building since it involves interaction and drives productivity with a people-centric building. Increase in work efficiency of the building can create a better experience, improve space management and efficiently manage assets while high effectiveness of reduced energy consumptions can also maximize electrification, actively manage energy and create positive energy building. High resource and work efficiency and an effective energy can lead to securing the environment and achieving a green building index rating. According to Wong (2020), a green building has a low carbon footprint, decreases environmental effect, and improves the internal atmosphere, all of which contribute to the residents' social well-being. In other words, it is a higher-quality structure that will function better over its lifetime. Smart building technology solutions include the growing emphasis on energy efficient buildings and reducing CO_2 emissions, growing government initiatives for the development of smart building projects, a growing need for integrated security and safety systems, and the rising adoption of IoT platforms within building automation technology (Atkinson, 2017). According to the Siva *et al.*, (2017), by 2050, building automation might save 4.62 gigatons of CO_2 because by switching to an automated system, it can save 10 to 20% on energy while also reducing the risk of human mistake that comes with manual building management. BAS implementation is to monitor and protect the environment and manage sustainable resources (Fraga-lamas et al., 2019). The sustainable development of BAS also can increase occupant comfort and productivity by enhancing indoor air quality. For example, aesthetics, lighting, acoustics, air quality and temperature (Spinsante *et al.*, 2017). BAS can also help to produce a better people-centric workplace environment by facilitating employee operations for optimum focus and productivity, including pleasant workplaces with good indoor air quality.

Scenario two is the least desirable situation where there is an ineffective energy consumption and low resource and work efficiency of BAS adoption in Malaysia. The failure to implement BAS will slow down the adoption and the society perceives that there is no need for BAS in a building and the generation is not willing to contribute to the technology. This is the worst scenario in terms of adoption as the society does not think BAS technology is able to provide the work efficiency and effectiveness to reduce energy consumption. Low resource of work efficiency can have a negative impact on the adoption of BAS in Malaysia. If there is low resource of work efficiency such as low human comfort in building will affect the productivity of the employees. Building automation enables more effective building operations, such as improved occupant comfort, cost savings via lower energy use, increased productivity, and better data insight. Multiple types of equipment can communicate with one another thanks to automation. As illustrated, motion detectors can be used in a space to tell the HVAC system when to alter the temperature to increase occupant comfort based on who is in the office, and when to turn off the system when no one is there. Integrating automation and communication amongst numerous systems is a terrific way to increase the efficiency of the facility. Building automation controls that allow building owners with rapid access to data via a web-based interface can detect issues and fine-tune any necessary adjustments from any location.

Scenario three, the process of BAS adoption in Malaysia still can be developed in future days. However, the researcher will face problems such as low productivity of employees and outcomes because of the high effectiveness of energy consumption of BAS adoption but low resources and work efficiency of BAS adoption in Malaysia. There are few problems if there is a low resource and work efficiency because the working environment has a significant impact on employee productivity, either in a negative or positive way (Chandrasekar, 2001). A better workplace atmosphere is thought to result in better outcomes and higher productivity. Employees will be more motivated and productive if the physical atmosphere of the office is improved. Dissatisfaction, cluttered workplaces, and the physical environment, according to various publications pertaining to the study of multiple offices and office buildings, are playing a big part in the loss of employee productivity (Carnevale 1992; Derek & Clements-Croome, 1997). For example, based on the information provided, BAS will adjust the temperature in the building to meet the demands of the employees, or its sensors will detect a need to improve the indoor air quality (Todd, 2021). A properly configured BAS can assist building operators in avoiding unwelcome calls from employees who are too hot or cold. The capacity to maximise the use of natural light, then adjust the amount of fresh air in the building, and more contributes to the worker’s comfort. When people begin to feel sleepy and lethargic, it is usually due to a lack of fresh air and oxygen. An effective energy consumption as the system regulates the operation of building components such as HVAC and lighting, facilities management costs decrease. Automation also reduces total energy use, resulting in a victory for the environment that can help a building achieve green certification. By incorporating automation, certain buildings can save up to 30% on energy expenses. BAS strives to reduce overall energy consumption, which may result in a variety of environmental benefits that keep building occupants healthier and happier. Therefore, this scenario may contribute to advantages of automation that result in cost savings through reduced energy use and waste reduction. The individual stress of a building on the electrical grid is also a consideration, with automation reducing this strain dramatically (BigRentz, 2021).

Scenario four was granted high resource and work efficiency and there are ineffective energy consumptions. Generally, high resource work efficiency in a building will facilitate work, improve comfort and experience in future, but with lack of effectiveness, reduced energy consumption will cause various problems especially involving the environment. This scenario is good for an organization to adopt this technology but must be concerned about the environment. High resource and work efficiency of the building managerial will influence the productivity in a workplace. Improving work efficiency can result in increased worker productivity as well as reduced energy costs. For example, salary costs typically account for a large amount of a business's expenses. When a minor percentage increase in productivity is multiplied by the number of employees, significant savings can be realised (Stamatescu *et al.*, 2020). For example, BAS changes the temperature and lighting levels of a building on a regular basis and automatically, making it easier to maintain an intelligent facility thus helping to reduce complaints by boosting tenant comfort. Installing BAS entails putting in place smart programmes and control systems that organise and structure the workplace, increasing overall productivity.

Furthermore, BAS not only keeps the employees comfortable and productive, but they also help the electrical systems run more efficiently without causing damage or costly maintenance. As a result, it prevents the everyday organisational activities from being disrupted by machine breakdowns or damages. When equipment is damaged, dysfunctional, losing efficiency, or approaching its replacement date, connected systems can generate alarms. Facility workers can reduce the number of on-site trips required simply to ascertain the nature of an issue by remotely monitoring systems. Unnecessary repair visits can be avoided entirely if a problem can be diagnosed and parts obtained ahead of time. Maintenance expenses are reduced, staff efficiency is improved, and energy expenditures are reduced (Wong, 2020). Besides, the ineffectiveness to reduce energy consumption is very dangerous. This is because the effectiveness of reduced energy consumption is a very important element that must be protected, especially involving environmental impact. BAS minimises the quantity of greenhouse gases discharged into the atmosphere by reducing a building's energy demand. To monitor and reduce water usage, a BAS can be linked into plumbing systems. These systems help buildings use resources more efficiently and lessen their environmental impact by minimising waste. Third parties, such as government authorities, can also use the systems to collect data and certify the amount of energy used by the building.

In this scenario, there is high resource and work efficiency of BAS adoption while it has a problem which is an ineffective energy consumption. The BAS adoption in Malaysia is able to be commercialised after the developing stage. However, when the researcher is not willing to focus on the energy consumption element, it will cause problems and be prone to the environment. Hence, the government must implement a variety of innovative regulatory approaches to reduce energy usage.

5. Conclusion

In conclusion, the first objective is to determine the key drivers that lead to smart building automation system adoption in Malaysia. Therefore, the two key drivers with the highest impact and uncertainty mean were chosen from impact-uncertainty analysis. Then, chosen key drivers were resource work efficiency and reduced energy consumption. Moreover, the second objective is to study the future trend of smart building automation system adoption in Malaysia. There are four scenarios on the future trends that were discovered from scenario building, which are sustainable development of BAS, stagnant or sluggish technology, achieve green certification and improve comfort and experience.

In a nutshell, this research is about BAS adoption that will provide the foresight of the BAS trend in Malaysia for upcoming years. This research will also add to the knowledge of this issue for everyone all around the world. Overall, all parties, including the government, green building developers, and consumers, must work together to improve and completely implement BAS in Malaysia.

Acknowledgement

The learning facilities and research guidance given by the bachelor's degree Final Year Project course enabled this research. The authors would like to express sincere gratitude to the Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia for its support.

References

Allen, B., Lippner, G., Chen, Y. T., Fotouhi, B., Momeni, N., Yau, S. T., & Nowak, M. A. (2017). Evolutionary dynamics on any population structure. *Nature*, 544(7649), 227-230.

Amirrudin, M., Nasution, K., & Supahar, S. (2020). Effect of Variability on Cronbach Alpha Reliability in Research Practice. *Jurnal Matematika, Statistika Dan Komputasi*, *17*(2), 223–230.

Anderson, J., & Rainie, L. (2018). The future of well-being in a tech-saturated world. Pew Research Center, 17.

Atkinson, W. (2017). *The Future Of Building Automation Systems | Electrical Contractor Magazine*. https://www.ecmag.com/section/systems/future-building-automation-systems

Azliana, N., Jamaludin, A., Ahmad, A., & Awang, N. F. (2019). *The Design of Promoting Building Energy Saver with Mobile Controller*. *December 2018*.

Behar, C., Bradshaw, F., Bowles, L., Croxford, B., Chen, D., Davies, J., ... & Von Bradsky, A. (2017). Building Knowledge: Pathways to Post Occupancy Evaluation.

BigRentz, I. (2021). *What is Building Automation ? 4 Environmental Benefits*. 1–14. https://www.bigrentz.com/blog/building-automation

Bolarinwa, O. A. (2015). Principles and methods of validity and reliability testing of questionnaires used in social and health science researches. Nigerian Postgraduate Medical Journal, 22(4), 195.

Chandrasekar, V., & Jayasumana, A. P. (2001, July). Radar design and management in a networked environment. In Technologies, Protocols, and Services for Next-Generation Internet (Vol. 4527, pp. 142-147). SPIE.

Carnevale, D. G. (1992). Physical settings of work: A theory of the effects of environmental form. Public Productivity & Management Review, 423-436.

Chin, J., & Lin, S. C. (2015). Investigating Users' Perspectives in Building Energy Management System with an Extension of Technology Acceptance Model: A Case Study in Indonesian Manufacturing Companies. *Procedia Computer Science*, *72*, 31–39.

Derek, T., & Clements-Croome, J. (1997). What do we mean by intelligent buildings?. Automation in construction, 6(5-6), 395-400.

Daniel, E. (2016). The Usefulness of Qualitative and Quantitative Approaches and Methods in Researching Problem-Solving Ability in Science Education Curriculum. *Journal of Education and Practice*, *7*(15), 91–100. https://doi.org/2222-288X

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. American journal of theoretical and applied statistics, 5(1), 1-4.

Fernandez-Carames, T. M., & Fraga-Lamas, P. (2019). A review on the application of blockchain to the next generation of cybersecure industry 4.0 smart factories. Ieee Access, 7, 45201-45218.

Gan, L., Garg, A., Wang, H., Mei, G., & Liu, J. (2021). Influence of biochar amendment on stormwater management in green roofs: experiment with numerical investigation. Acta Geophysica, 69(6), 2417-2426.

Ghosh, B., Ghosh, M. K., Parhi, P., Mukherjee, P. S., & Mishra, B. K. (2015). Waste printed circuit boards recycling: an extensive assessment of current status. Journal of cleaner production, 94, 5-19.

GlobeNewswire. (2020). *Emerging Technology Roadmap in the Global Building Automation Systems (BAS) Market*.https://www.globenewswire.com/news-release/2020/07/29/2069260/28124/en/Emerging-Technology-Roadmap-in-the-Global-Building-Automation-Systems-BAS-Market.html

Huang, Q., Lu, C., & Chen, K. (2017). Smart Building Applications and Information System Hardware Co-Design. In *Big Data Analytics for Sensor-Network Collected Intelligence*. Elsevier Inc.

InfoSystems. (2017). *Creating a Green Building Environment with a Building Automation System*. http://infosystems.mu/creating-a-green-building-environment-with-a-building-automation-system

Jia, R., Jin, B., Jin, M., Zhou, Y., Konstantakopoulos, I. C., Zou, H., Kim, J., Li, D., Gu, W., Arghandeh, R., Nuzzo, P., Schiavon, S., Sangiovanni-Vincentelli, A. L., & Spanos, C. J. (2018). Design Automation for Smart Building Systems. *Proceedings of the IEEE*, *106*(9), 1680–1699.

Jumrukovska, E. (2019). *What Is A Building Automation System (BAS)? (Functions And Benefits) | News | Open Sourced Workplace*. https://www.opensourcedworkplace.com/news/what-is-a-building-automation-system-bas-functions-and-benefits

Kang, B., Kim, D., & Choo, H. (2017). Internet of Everything: A Large-Scale Autonomic IoT Gateway. *IEEE Transactions on Multi-Scale Computing Systems*, *3*(3), 206–214.

Kharchenko, V., Ponochovnyi, Y., Boyarchuk, A., & Qahtan, A. S. (2017). Security and availability models for smart building automation systems.

Lim, R., Ruslan, I., Susatya, H., Wibowo, A., Handojo, A., & Sutjiadi, R. (2016). Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015). *Lecture Notes in Electrical Engineering*, *365*(Icesti 2015), 457–464.

Liu, J., & Sheaffer, P. (2018). ISO 50001 for US Commercial Buildings-Current Status and Opportunities.

Luo, M., Hong, Y., & Pantelic, J. (2021). Determining Building Natural Ventilation Potential via IoT-Based Air Quality Sensors. Frontiers in Environmental Science, 144.

Minchev, Z., Boyanov, L., & Georgiev, S. (2013, June). Security of Future Smart Homes. Cyber-Physical Threats Identification Perspectives. In Proceedings of National Conference with International Participation in

Realization of EU HOME/2010/CIPS/AG/019 project, Sofia, Bulgaria (pp. 165-169).

Simmonds, D. M., & Bhattacherjee, A. (2015). Smart Systems, Smarter Living: An Empirical Study of the Building Automation System in Organizations. In Proceedings of the 2015 Pre-ICIS Workshop.

Siva, V., Hoppe, T., & Jain, M. (2017). Green buildings in Singapore; Analyzing a frontrunner's sectoral innovation system. *Sustainability (Switzerland)*, *9*(6), 1–23.

Spinsante, S., Ciattaglia, G., Del Campo, A., Perla, D., Pigini, D., Cancellieri, G., & Gambi, E. (2017). A LoRa enabled building automation architecture based on MQTT. *2017 AEIT International Annual Conference: Infrastructures for Energy and ICT: Opportunities for Fostering Innovation, AEIT 2017*, *2017-January*, 1–5.

Stamatescu, G., Stamatescu, I., Arghira, N., & Fagarasan, I. (2020). Cybersecurity Perspectives for Smart Building Automation Systems. *Proceedings of the 12th International Conference on Electronics, Computers and Artificial Intelligence, ECAI 2020*.

Stimmel, C. L. (2015) *Big data analytics strategies for the smart grid* (Boca Raton, FL: CRC Press) ISBN 9781482218282 URL http://proquest.tech.safaribooksonline.de/9781482218282

Supramaniam, T., Ibrahim, R., Hassan, S. M., & Bingi, K. (2017). Development of WirelessHART adapter with industrial transmitter for process monitoring. *Proceedings of the 2017 IEEE International Conference on Signal and Image Processing Applications, ICSIPA 2017*, *September*, 294–298.

Todd, H., & Emsley, P. (2021). Development and assessment of CootVR, a virtual reality computer program for model building. Acta Crystallographica Section D: Structural Biology, 77(1), 19-27.

Van Khuc, Q., & Tran, D. T. Primary data.

Verma, H., Jain, M., Goel, K., Vikram, A., & Verma, G. (2016). Smart home system based on Internet of Things. *Proceedings of the 10th INDIACom; 2016 3rd International Conference on Computing for Sustainable Global Development, INDIACom 2016*, 2073–2075.

Visconti, A., Le Roy, C. I., Rosa, F., Rossi, N., Martin, T. C., Mohney, R. P., ... & Falchi, M. (2019). Interplay between the human gut microbiome and host metabolism. Nature communications, 10(1), 1-10.

Voigt, T., & Osterlind, F. (2008, September). CoReDac: Collision-free command-response data collection. In 2008 IEEE International Conference on Emerging Technologies and Factory Automation (pp. 967-973). IEEE.

Wong, C. F. (2020). *Need for Construction Industry 4.0 — Wong Chee Fui*. Malay Mail. https://www.malaymail.com/news/what-you-think/2020/02/05/need-for-construction-industry-4.0-wong-chee-fui/1834761

Yudelson, J. (2020). What is a Green Building? In *Marketing Green Building Services*.