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ADAPTING TO A NEW NORMAL DURING COVID-19: LEVERAGING THE SMART BUILDING SYSTEM WITH BIM INTEGRATION FOR LIFECYCLE SUSTAINABILITY

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Abstract

The COVID-19 outbreak brought challenges to the education sector in Malaysia as schools were shut down and later on, operate under strict standard operating procedures (SOP) and guidelines. This situation caused inconvenience to school authorities as the education process was significantly affected. Smart building systems that integrate various technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), mechanisms and robotics and building management systems allow school authorities to operate the schools under the new norm. Therefore, this research was conducted to propose a safe operation of the physical teaching and learning process in schools by leveraging smart building systems. A qualitative method was adopted which involved the participation of five schools in Kedah. Findings revealed that smart building systems are suitable to be implemented in schools to create a safe environment and operation for the physical teaching and learning process under the new norm.

***Keywords**:* Smart buildings system; built environment; COVID-19; schools; teaching and learning process

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INTRODUCTION

In 2019, the outbreak of Coronavirus disease 2019 (COVID-19) has caused the global health crisis which directly affects human health and social functions. Some statistics and studies also proved that the built environment is one of the main factors that triggered COVID-19 transmission among the occupants in a building as the virus can spread easily and rapidly in confined and crowded spaces (Azuma et al., 2020). The Malaysian government introduced the Movement Control Order (MCO) nationwide starting on 18 March 2020 to curb the spread of COVID-19 infection in Malaysia (New Straits Times, 2020). All education institutions were closed due to the implementation of MCO. Thus, all physical classes were replaced with online classes. However, the closure of the schools caused some inconveniences to the teachers and students as online classes come with a plethora of challenges and problems.

The implementation of MCO has succeeded in reducing the number of reported COVID-19 cases in Malaysia. The Ministry of Education announced the reopening of schools in phases after the COVID-19 situation is manageable (Hana and Tharanya, 2020). However, the re-opening of the schools requires school authorities to follow all the standard operating procedures (SOPs) and guidelines released by the Malaysian authorities. This situation created additional workload and stress for school authorities as they had to put extra effort and time into operating the school to ensure that schools are safe for conducting physical teaching and learning processes under the new norm (Nuradzimmah, 2021).

The COVID-19 outbreak not only had negative consequences to all sectors but also created a state of uncertainty in the world (Abdul Latip et. al., 2021). This is evidenced in November 2020; all schools were forced to close again as the COVID-19 cases increased in Malaysia. The flip-flopping decision made by the government raised concerns and caused inconveniences to various parties, which also affected students' academic progress and caused long-term disruptions to their education. Thus, the closure and re-opening of the schools is not the best solution, as people need to learn to live with COVID-19.

RESEARCH BACKGROUND

In ensuring the safety of the students and teachers, the Ministry of Education prepared a guideline for school operation and management that is in line with guidelines prepared by the Ministry of Health and National Security Council. Among the guidelines are the requirement of temperature and symptom screening of the students at the school entrance, sanitising and cleaning the classrooms before and after every school session and practising physical distancing of 1 metre apart between students. On top of that, schools must also establish suitable movement routes to control the students' movement within the school compound. Furthermore, to minimise crowds at the school canteen, students are encouraged

to pack food from home or buy packed food from the school canteen operator and have their meals at their respective desks during recess.

All these measures and regulations are necessary to minimise the risks of spreading the virus. However, this has created an additional workload for the school administrators and teachers. All teachers and school administrators had to take additional measures to ensure the school was clean and safe. For this, teachers and school administrators must reach the school early to record students' temperature, ensure all the classrooms are clean and sanitised, and also monitor students during recess to make sure all students practise physical distancing. These additional tasks burdened the teachers and school administrators and consumed lots of time and energy. This has created additional stress on school authorities as they need to ensure that the schools are safe for conducting physical teaching and learning (Nuradzimmah, 2021).

In creating a healthy and safe environment for the students and teachers, schools need to transform by leveraging technology in surviving this health crisis. The integration of digital technologies in the construction industry has created the existence of smart buildings (Tung et al., 2021). Smart buildings which were previously used to improve building efficiency can now be used to create a safe and healthy environment. The concept of smart buildings which are sometimes referred to as 'intelligent buildings' or 'automated buildings', arose a few decades ago. There is no fixed definition of smart buildings and Wigginton found that there are more than 30 different definitions that are related to smart buildings (Wigginton, M & Harris, J., 2002). The first definition of the smart building only focuses on the technical aspects without considering occupants' interaction with the buildings (Powell, J.A., 1990). However, the definition of smart buildings kept changing based on the requirements of the occupants. Nowadays, smart buildings have learning capabilities, gather information and can carry out regulated performance regarding the building occupancy and its relations with the surrounding environment (Yang, J. & Peng, H., 2001). The smart building today is a pro-active entity, not only just responding and reacting to performance requirements but also learning and adjusting to meet optimum performance based on the surrounding environment and occupants' requirements.

The application of smart building technologies can create more efficient building management through proper environmental management and ventilation, occupancy monitoring, maintaining the cleanliness of the building, and touch-free technology to avoid contact with surfaces and others. According to Kaklauskas et al. (2010), the intelligent sensors that are installed at shared facilities such as lifts, elevators and automatic doors enable building occupants to interact and utilise them touch-free. Hence, these features can minimise the chance of cross-infection happening among the occupants. Furthermore, the thermal cameras and temperature sensors installed at the buildings can measure

building occupants' temperature automatically and detect any occupants with high body temperature or fever (Degha et al., 2019). Smieszek et al. (2019) stated that indoor air quality and the heating, ventilation, and air conditioning (HVAC) system play a vital role in decreasing the chance of airborne transmission of the viruses. The Internet of Things (IoT) and Artificial Intelligence (AI) were being implemented in some HVAC systems to enhance their efficiency to purify the indoor air. The sensors can detect any contaminants or viruses in the air and let the system take the corresponding action to eliminate those contaminants in the air to enhance the air quality (Arup, n.d.).

Social distancing and contract tracing are very important during the re-opening of various sectors and social functioning under the new norm. Therefore, some IoT applications were adopted during the COVID-19 pandemic including the IoT-based wearable devices and crowd monitoring devices. (Mohammad Nasajpour et al., 2020). EasyBand is one of the examples of wearable IoT devices that will alert users to practise social distancing. Spot, a dog-like AI-based four-legged robot equipped with cameras and intelligence sensors is an example of a crowd monitoring device which was deployed in public areas in Singapore to encourage people to practise social distancing (Wray, 2020). In Malaysia, the Royal Malaysia Police (PDRM) uses drones to monitor SOP compliance at bazaars around the Klang Valley and reprimand anyone who does not comply with the SOPs through the drone's loudspeaker (Bernama, 2021). Furthermore, UVD Robots, developed by a Danish company, were adopted in China hospitals to disinfect rooms (Ackerman, 2020) because it is more efficient and saves time. The usage of these technologies helps to minimise the manpower involved in making sure that all the guidelines imposed by the government are adhered to.

However, the study on the implementation of the smart building concept in existing schools is very limited, creating the need to further investigate its application to create a safe and healthy environment for schools' operation. Thus, this research aims to propose a safe operation of the physical teaching and learning process in schools. This is achieved by identifying the suitable smart building system that is suitable as a prevention and control measure of COVID-19; prioritising the suitable smart building system that is suitable to be installed at schools and formulating a guideline for the existing school to adopt with the new norm based on the smart technologies.

RESEARCH METHODOLOGY

To determine the study area and grasp the current information on the topic, a literature review was conducted. The review included English and Malay language articles from databases such as Emerald, Scopus, and ScienceDirect, as well as conference papers, dissertations, and official government web pages. Articles were studied from the year 2018 to 2022 using specific keywords such

as smart building systems, built environment, COVID 19, Internet of Things (IoT), Artificial Intelligence (AI), schools, as well as Boolean search commands such as "and" and "or." Articles which are published in 2018 to 2022 only were chosen as references to ensure the accuracy of the data and information. The exclusion criteria were investigated using a sample that was not representative of industry participants and was unrelated to the building sector. For data extraction and analysis, Endnote and Microsoft Excel were utilised. The findings of the literature research were also used to develop semi-structured interview questions. A qualitative research design has been chosen, which involved 5 case studies. The five case studies were selected based on several criteria which include the school size and the location of the school. A total of 2 public schools and 3 vernacular schools were chosen for this research. Each selected school has an average of 1205 students and 61 academic staff. Besides, all the selected schools were in the town area. A semi-structured interview method and observations were used in collecting the data. This method provides both researchers and participants opportunities to discuss the topic in more detail to determine the relative emphasis on the topic. The data analysis was framed using findings identified in the literature to incorporate the study into the existing body of knowledge.

Three sections were created for the semi-structured interview questions. It begins with Section A which focuses on the respondents' backgrounds, Section B identifies the approaches that are adopted by the respondents to overcome all the challenges when operating schools under the new norm, and Section C identifies the agreement of the respondents toward the necessity of the statement. A total of 12 respondents which were school administrators, school principals and teachers agreed to participate in the interview sessions. They were chosen as respondents for this research because they have an in depth understanding of the conditions and strategies adopted when operating the schools under the new norm. On top of that, observations were conducted at these five schools to collect additional and supplementary information to strengthen the reliability of the interviews. Thematic analysis was used in analysing the collected data which included familiarisation, coding, generating themes, reviewing themes, defining, and naming themes and writing up is adopted to analyse the data collected to formulate a conclusion on the issues concerned. Furthermore, gap analysis is conducted to allow researchers to make comparisons between the current conditions of the schools and the expected conditions of the schools after implementing the proposed smart building system in schools.

RESULT AND FINDINGS

Case Study Analysis

All data obtained from the case studies were analysed. The data collected from the interviewees through interview sessions were analysed using thematic analysis. Table 1 shows the finding of the 5 case studies involved. Findings revealed that a lot of manpower was needed in implementing the SOPs outlined by the government, which caused some degree of inconvenience to the school authorities.

Table 1: Findings of the 5 case studies.

Activity	Methods Applied	Case Study				
		1	2	3	4	5
Temperature Screening & Symptom Checking	Teachers record students' body temperature manually using a digital thermometer.	✓	✓	✓	✓	✓
	Develop and implement a special QR code system to record students' body temperature and attendance.					✓
	Digital thermometers with stands were prepared at school entrances for temperature screening.		✓			
Physical Distancing	Teachers on duty monitor students during school dismissal time.	✓	✓	✓	✓	✓
	Using CCTV to monitor students and make an announcement to warn students.	✓				
	Staggered school dismissal time.	✓	✓	✓	✓	✓
	Prepare floor markings to encourage social distancing practice.	✓	✓	✓	✓	✓
	Demerits will be imposed on those students who failed to practise physical distance.		✓			
	Introduce a one-way pedestrian plan.		✓			
Disinfection	School workers disinfect the school premises.	✓	✓	✓	✓	✓
	Students disinfected their respective tables and chairs.	✓	✓		✓	
	Automatic hand sanitiser dispensers were installed in several locations of schools to allow occupants to sanitise their hands.	✓		✓		✓
	Disinfection tunnels were installed at school entrances to allow students to sanitise themselves once they enter the school compound.			✓		

Appoint disinfection and sterilisation contractors to disinfect school premises regularly.	✓

Source: Author

Participants involved in the interview were also asked about the suitable smart building applications to be implemented in school to ease their burden. Nine smart building applications were obtained from the literature review and for the interviewees to rank based on their personal opinions regarding the need and expectations of these applications. From the interview findings, it shows that the majority of the respondents (93%) choose IoT wearable devices to alert people to keep maintaining social distance all the time as the most necessary smart technologies that should be implemented. On the other hand, the smartphone application to record people who were in close contact with each other is the least preferred application which is chosen by 33% of the respondents. Table 2 shows the agreement on the necessity of each application by respondents.

Table 2: The agreement on the necessity of each application by respondents.

Applications	Category	Frequency (%)
IoT wearable devices to alert people keep maintaining social distancing all the time	Internet of Things (IoT)	92
AI disinfection robot that utilises UVC light to disinfect common areas	Artificial Intelligence (AI)	83
Thermal cameras and temperature sensors to measure occupants' body temperature	Smart Building System	75
An AI-based robot to encourage people to practise physical distancing in public areas	Artificial Intelligence (AI)	67
An AI system equipped with AI and infrared sensor to detect people's body temperature	Artificial Intelligence (AI)	58
Automatic doors	Smart Building System	50
Smart sensors that identify the areas that are visited by many people or frequently used surfaces (handles, handrails)	Smart Building System	50
Smart Heating, Ventilation & Air Conditioning (HVAC) system that can improve indoor air quality automatically	Smart Building System	42
Smartphone applications record people who were in close contact with each other	Internet of Things (IoT)	33

Source: Author

Current State and the Future State of Schools

The gap analysis was conducted to compare between the current conditions and the ideal conditions of the schools after implementing the proposed smart building system in schools with the aim to improve the current conditions through several actions to achieve the ideal conditions.

Figure 1, Figure 2 and Figure 3 show the summary of the gap analysis. The current state of the schools conducting temperature screening and symptom check manually and the tools that were used by the school authorities were very limited such as the handheld electronic thermometers.

Besides, it was found that all the disinfecting works were conducted manually. The schools' cleaners are required to disinfect or clean the classrooms before and after the school sessions. However, this consumes a lot of time and causes some inconvenience for those schools that have both morning and afternoon sessions as they need to share the same classroom. The disinfection works might not be effective as school cleaners could miss cleaning certain areas. For physical distancing, several strategies were adopted including staggered dismissal school time and a one-way pedestrian plan and markings to ensure everyone practises physical distancing. However, it is difficult to make everyone follow the physical distancing guideline because the strategies applied were not effective enough.

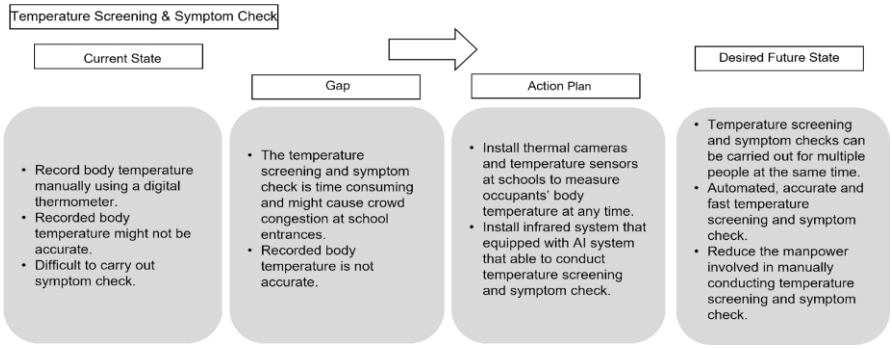

Figure 1: Summary of gap analysis for temperature screening and symptom check.
Source: Author

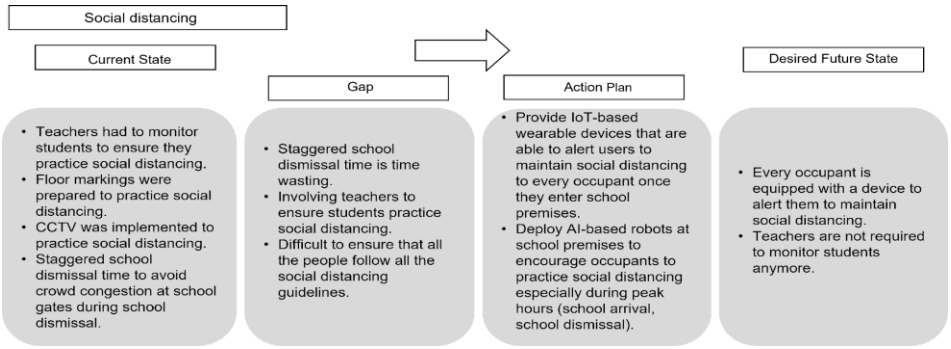

Figure 2: Summary of gap analysis for social distancing.
Source: Author

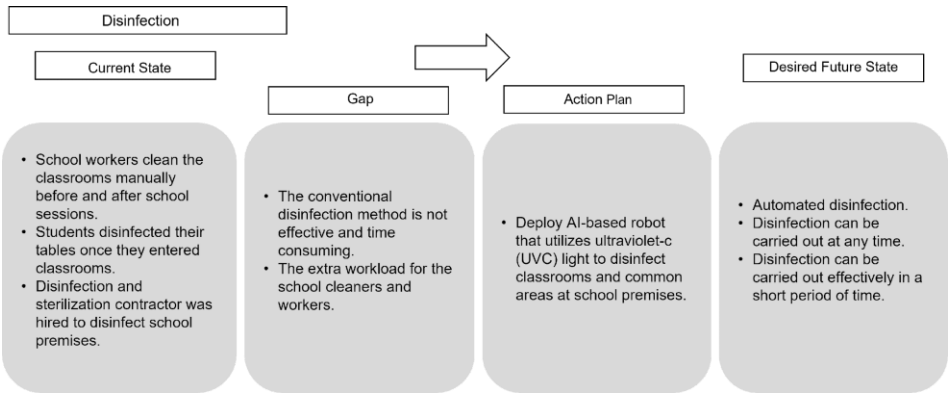

Figure 3: Summary of gap analysis for disinfection.
Source: Author

DISCUSSION

Proposed Guideline

Researchers can identify the challenges and problems faced by the school authorities to operate the schools under the new norm from the research findings. The main challenges including the guidelines outlined by the government have increased school administrators and teachers' workload and students' academic performance were greatly affected due to the closing and reopening of the schools. Hence, a proposed guideline is formulated based on the research findings to help the school authorities overcome these challenges.

The proposed guideline is required to ensure that the schools can achieve the ideal future state. It also plays an important role to act as a recommendation to formulate a guideline for the schools to create a safe physical teaching and learning environment under the new norm. Figure 4 shows the proposed guideline.

The proposed guideline includes the top five applications as over 50% of the respondents choose them as the applications that are suitable to be implemented in schools. The five applications are:

1. IoT-based wearable devices to alert people to keep maintaining physical distance all the time.
2. An AI-based robot that utilises ultraviolet-c (UVC) light to disinfect common areas.
3. Thermal cameras and temperature sensors to measure occupants' body temperature.
4. An AI-based robot to encourage people to practice physical distancing in public areas.
5. An AI system equipped with an AI and infrared sensor to detect people's body temperature.

Under the proposed guideline, temperature screening and symptom checks can be conducted by implementing AI infrared sensors, thermal cameras and temperature sensors at schools. This can reduce the manpower involved in conducting one-to-one temperature screening manually and can also detect any occupants with high body temperature and suspicious symptoms accurately and rapidly. Thus, temperature screening and symptom checking will not be time and energy-consuming anymore with the implementation of these applications. For physical distancing, IoT-based wearable devices and AI-based physical distancing robots were proposed. Both applications aim to alert students, teachers, and school administrators to practise physical distancing within the school compound. Implementing these applications can reduce the teachers' burden as they do not need to monitor and supervise students, especially during school dismissal time. Furthermore, the AI-based disinfection robot was proposed. The current method that the schools adopted to disinfect and clean the school compound is very time consuming and not effective. Implementing a smart building system that consists of an AI-based disinfection robot able to conduct disinfection and cleaning works according to optimal cleaning routines which are formulated based on current or historical building occupancy information. Therefore, disinfecting works can be conducted effectively and effortlessly.

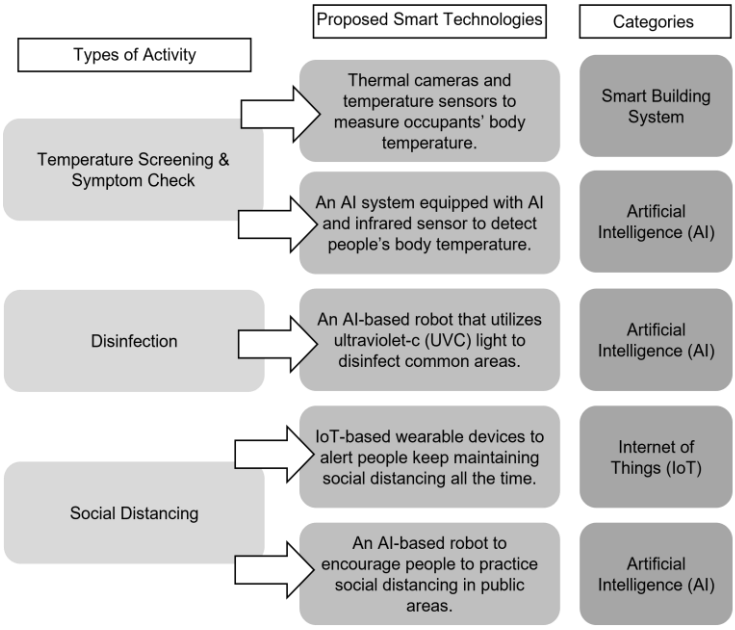

Figure 4: The proposed guideline.
Source: Author

School authorities can create or achieve the ideal future state which is to create a safe physical teaching and learning environment under the new norm with this proposed guideline. Once the smart building system is implemented in the existing schools, it can reduce the manpower involved such as teachers, school staff and school administrators in conducting certain tasks in the guidelines outlined by the government. Thus, the workload of the teacher will be minimised, and they can fully concentrate on teaching the students in school. Besides, schools were built to create the space for students to learn. The closure and reopening of the schools will affect some students' academic performance as they do not have a suitable alternative environment to learn when schools were closed. Thus, it clearly shows that schools are the perfect places for students to learn. A safe physical teaching and learning environment can be created by leveraging the smart building system. According to Cleveland (2021), some schools in the United States and some countries in Europe already implemented smart technologies to ensure that the buildings can provide a healthy and safe learning space during the post-COVID-19 pandemic. However, implementation of smart building systems in existing schools in Malaysia is very limited. It is a huge challenge for the school authorities to create a safe and healthy learning environment without the aid of these smart technologies, especially in a post-COVID pandemic world. Furthermore, infectious diseases and pandemics are cyclical and unpredictable and will strike again in future. Hence, the

implementation of a smart building system with various smart technologies discussed earlier would be a key contributor to creating a safe and healthy environment for occupants in a post-pandemic world.

CONCLUSION

This research identified and highlighted the challenges and problems faced by the schools' authorities during the closure, re-opening and operating of the schools under the new norm. It also revealed that the current state of the school operating under the new norm is time and energy-consuming due to the guidelines and SOP outlined by the Malaysian government. Thus, the implementation of a smart building system in schools can reduce additional work and inconvenience when operating the school under the new norm. The teaching and learning process can be conducted physically and safely under the new norm by leveraging the smart building system. For instance, physical education and learning will not become a challenge anymore for the teachers and students under the new norm. Thus, the students' education will not be affected by the pandemic.

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