ADOPTION OF GREEN BUILDING TECHNOLOGY (GBT) IN MANAGING COVID-19 RISK FOR PUBLIC FACILITIES IMPROVEMENTS

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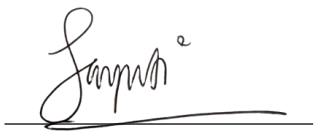

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ABSTRAK

Pada Disember 2019, wabak Penyakit Novel Coronavirus (COVID-19) bermula di Wuhan, China telah merebak keseluruh China, kemudian merebak ke seluruh dunia. Bangunan telah menjadi sambungan penting dalam pencegahan dan kawalan COVID-19, yang merupakan lokasi penting untuk kerja dan kehidupan seharian masyarakat. Rakyat diperintahkan untuk kekal berada di dalam rumah telah membuatkan masyarakat lebih menghargai kepentingan bangunan boleh melindungi mereka daripada kebimbangan kesihatan seperti COVID-19, di samping menekankan keperluan bangunan hijau. Bangunan hijau menyediakan udara yang lebih bersih dan penebat, pengudaraan dan pencahayaan yang lebih baik untuk persekitaran kerja di rumah yang lebih sihat, selesa dan produktif. Menurut kaji selidik lpsos, pelaksanaan TBH menggalakkan amalan cekap tenaga dan air, sekali gus mengurangkan bil utiliti isi rumah, yang telah meroket sejak mengosongkan kemudahan pejabat. Selain itu, World Green Building Council melaporkan bahawa bangunan kini memainkan peranan penting dalam mencegah dan mengawal virus COVID-19. Malah, bangunan hijau boleh menyumbang kepada kesihatan kita semasa pandemik di seluruh dunia pada masa kini dan boleh membantu mencegah pandemik pada masa akan datang. TBH atau lebih dikenali sebagai Pembinaan Hijau, iaitu pelaksanaan reka bentuk yang bertanggungjawab terhadap alam sekitar dan cekap sumber sepanjang kitaran hayat struktur, bangunan atau ruang komersial. Selain melindungi sumber semula jadi yang berharga, bangunan hijau juga meningkatkan kualiti hidup masyarakat. Penerimaan TBH mempunyai banyak kesan ke atas kemampanan penghuni bangunan semasa pandemik Covid-19. Penyelidikan ini bertujuan untuk memberikan pendapat dan idea mengenai penggunaan GBT dalam mengurangkan risiko jangkitan COVID-19 dan meningkatkan kemudahan awam untuk daya tahan pandemik yang lebih baik bagi memerangi situasi pandemik.

ABSTRACT

In December 2019, the Novel Coronavirus Disease (COVID-19) outbreak began in Wuhan, China, spreading throughout China and globally. The building has become a critical connection in preventing and controlling COVID-19, an important location for people's work and living. Despite the struggles, being forced to remain indoors has increased our appreciation for how buildings can protect us from health risks such as COVID-19 while emphasizing the need for green buildings. To create a work-at-home environment that is both healthier and more comfortable for employees, eco-friendly construction methods are increasingly prevalent. According to an Ipsos survey, the GBT implementation promotes energy- and water-efficient practices, reducing households' utility bills, which have skyrocketed since vacating office facilities. Buildings also have an essential role in preventing and controlling the COVID-19 virus, according to the World Green Building Council (WGBC). Furthermore, during a global pandemic, green buildings can contribute to our health and help prevent the next. GBT, also known as Green Construction, is the application of environmentally responsible and resource-efficient design throughout the lifecycle of a structure, building, or commercial space. In addition to protecting precious natural resources, green buildings also enhance our quality of life. A healthy and comfortable living environment is necessary for mental and physical health. During the Covid-19 epidemic, Green Building Technology (GBT) adoption had multiple consequences on the tenants' sustainability. This research aimed to provide opinions and ideas regarding utilizing GBT to reduce the risk of COVID-19 infection and enhance public facilities for better pandemic resilience while combating the pandemic situations.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ASBG	Assessment Standard for Green Building
COVID-19	Coronavirus Disease 2019
GBT	Green Building Technology
HVAC	Heating, Ventilation, and Air Conditioning
HEPA	High-Efficiency Particulate Air
IEA	International Energy Agency
IEQ	Indoor Environment Quality
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
MCO	Movement Control Order
OECD	Organisation for Economic and Co-operation Development
RII	Relative Importance Index
SDGs	Sustainable Development Goals
UN	United Nation
UV	Ultraviolet
UVGI	Ultraviolet Germicidal Irradiation
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

According to the Coronavirus disease 2019 (COVID-19) Situation Report – 72 (WHO, 2020: (Sheng, 2020), disease transmission can be halted through a combination of adaptive methods that promote community resilience and social connection to enable rapid recovery. Paganini et al. (2020) recommend crucial infrastructure improvements for the COVID-19 pandemic based on the current health infrastructure and facilities. From the perspective of the sustainability of the public health system, much attention is needed from governments for infrastructure planning concerning the Covid-19 pandemic in Vietnam (La *et al.*, 2020). However, due to Covid-19 pandemic risks, these infrastructure developments have to ensure community health and safety aspects collaboratively for their resiliency with the assimilation of sustainability elements, namely environment, economy, and society.

Green Building Technologies (GBT) is a method that can be used to manage the issues of climate change and sustainability. Therefore, Malaysia needs to ensure its construction industry is moving towards supporting the global agenda on climate change and sustainability. As a result, it is necessary to employ environmentally friendly construction techniques in order to achieve project requirements and gain a competitive edge in the construction industry.

Green Building Technology applies ecologically responsible and resource-efficient design across a structure, building, or commercial space's life cycle. In addition to helping the environment, green buildings also improve human well-being. The green

architecture approach also emphasizes creating a pleasant, comfortable indoor environment (IEQ). There must be a coordinated effort amongst those involved in the disciplines of public health, climate change, civil society, and green construction to improve community resilience and population health (Houghton and Castillo, 2017).

Green buildings create healthier, more pleasant, and more productive indoor environments by reducing pollutants in the air and improving insulation, ventilation, and lighting. However, the current study indicates that COVID-19 can be spread by indoor airborne transmissions, particularly in crowded and poorly ventilated spaces (Kenichi Azuma, 2020). Therefore, optimal air quality must be maintained to prevent the spread. This necessitates inventive modifications to the current indoor and outdoor infrastructure to positively affect the residents of even the most densely occupied spaces (Tokazhanov *et al.*, 2020). As a consequence of the above, preventative and control measures need to be established to protect the health and safety of the residents. These efforts should be focused on enhancing public facilities to make them more accessible and systematic.

Healthy buildings are more prevalent as the world adjusts to a situation where we may return to offices, restaurants, and shopping malls and resume our regular lives. This approach comprises capacity restrictions, staggered work schedules, physical distancing arrangements, better disinfection procedures, and the use of personal protective equipment (PPE). As experts reconsider how building systems might prevent the development of COVID-19, technology has also become a central position.

Since the coronavirus outbreak, public buildings have been challenged to provide safe and healthy community shelter facilities in response to extreme weather, wildfires, and other catastrophes. The infrastructure should be efficiently upgraded to enhance safety, sustainability, and resiliency and provide the flexibility to respond to various

public health and natural disasters. Nevertheless, as evidenced by the COVID-19 outbreak, many facilities require modernization to satisfy the new norms. This also challenges the conventional design and construction strategy for residential and public buildings in the post-COVID-19 era (Kaklauskas *et al.*, 2021). Post-COVID-19 architecture is an ongoing concept that applies to new and existing buildings with healthy features (Tokazhanov *et al.*, 2020). The healthy building idea focuses primarily on establishing an inviting and comfortable indoor environment, as evaluated by indoor environmental quality (IEQ) (Šujanová *et al.*, 2019). In most heavily populated buildings, a healthy IEQ is anticipated to have suitable physical, mental, and social effects on the occupants (Al horr *et al.*, 2016). The IEQ refers to the quality of the indoor living environment within a building (Lai *et al.*, 2009). Multiple elements, such as thermal, optical, auditory, and chemical, influence the quality of the indoor environment (Magrini and Lisot, 2015).

The current COVID-19 epidemic emphasizes the significance of anticipating future development in construction techniques that accelerate the building of emergency structures such as COVID hospitals and quarantine tents. This research aims to highlight the significance of a healthy building environment through the implementation of green building technology. It is necessary to ensure that green building and the use of green technologies can balance social and economic objectives in emergency conditions. Thus, public facilities can continue to function normally despite environmental constraints. In particular, the World Green Building Council reports that "buildings now play an important role in preventing and controlling the COVID-19 virus" (2020). Indeed, green buildings can contribute to our health during the current global pandemic and could help prevent the next one.

In addition, this study was expected to provide a better understanding of how the influence of green technologies in public buildings might contribute to managing the COVID-19 risk. It will also identify the public facilities necessary for implementing this green technology. Evaluating the influence factors will give essential assurance and an optimal environment for preventing and controlling COVID-19.

1.2 Problem Statement

Public infrastructures in Malaysia are growing in number and size (Amiril *et al.*, 2014). This scenario results from the growing population in 2019, projected to reach 32.6 million, rising from 32.4 million in 2018 (DOSM, 2020). This situation has contributed to an increased level of health and safety risks that requires Malaysia to focus on community resilience collaboratively with the construction industry's strategic plan, which is responsible for sustainable infrastructure development. However, Agogo et al. (2019) conclude that poor infrastructure, human shortages, and other compounding factors make it difficult for many communities to plan for emergencies properly, let alone respond and recover when outbreaks occur.

In the context of COVID-19 conditions, the nation should establish a particular design guideline or policy for environmentally and user-friendly public facilities during the outbreak. It comprises insufficient operation strategies for ventilation and air filtering in public areas, inadequate requirements for disinfection of public facilities, an overabundance of occupants relative to the building's design, and the absence of a building emergency mechanism.

This research examined how using Green Building Technology during this pandemic strengthens community resilience. In other words, it highlights the importance

of the convenience and facilities for implementing epidemic prevention and control, reducing the risk of infection and preventing cross-infection, promoting and ensuring the health of occupants while in public, and providing a stable work and living environment. It also highlights the application of Green Building Technology, which positively impacts the prevention and control of COVID-19 and the management of buildings in response to community health and safety concerns.

1.3 Research Objectives

This research is performed to achieve these objectives:

1. To identify the contribution of Green Building Technology in the fight against the COVID-19 pandemic.
2. To examine the types of public facilities relevant to Green Building Technology adoption in the context of COVID-19, as perceived by the public.
3. To compare technical and non-technical factors that influence the adoption of Green Building Technology for public facilities improvements in the context of COVID-19.

1.4 Scope of Work

This study evaluates the benefits of green building technologies for COVID-19 risk management in public buildings. The survey scope includes engineering sectors such as the construction industry, architectural firms, contractors, designers, and developers.

This research focuses on the two main components of green building: indoor environmental quality and water efficiency. In addition, this research measures the

weightage between technical and non-technical factors that influence green building technology adoption in managing COVID-19 risks at the time of the outbreak—a more precise understanding of the adoption of green building technology in managing COVID-19 risk.

1.5 Dissertation Outline

The thesis contains five chapters. The first chapter provides an overview of the research, including the background research, problem statement, research objectives, and scope of work. The literature review part of Chapter 2 describes previous studies on the advantages of green building technology and current studies on the relationship between green building technology and Covid-19, including sustainability aspects. Chapter 3 discussed the study's approach. This chapter explains the data collection and research result extraction processes. This chapter describes the steps involved in data collection and the interpretation of research results.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Public health has never been in such a state of emergency as it is presented today. Government lockdowns appeared to be the only solution, virtually putting an end to economies around the world. Consequently, the United States has been enduring its economic crisis since the Great Depression. To deal with the situation, many people's lives were radically changed in various ways (Kaklauskas *et al.*, 2021). Coronavirus disease, COVID-19, appears to have a global audience during this stage. As a result, public health and emergency response systems must be prevented and regulated.

The virus was somewhat transmitted through airborne droplets and produced respiratory illness. When people cough, sneeze, speak, sing, or breathe, small liquid particles from the mouth or nose of an infected person disseminate the virus. When breathed at close range, virus-carrying airborne particles can infect a second human (WHO, 2020). The sickness spread more quickly in indoor spaces that were overly crowded, had poor ventilation, and were places where people tended to spend more time. This is because aerosols can linger in the air or spread beyond a normal conversation distance range. As a result of the pandemic caused by the COVID-19 virus, community activities are being restricted, and everyone is required to remain indoors during the movement control orders.

Therefore, residential or business buildings become the primary locations, as individuals are required to play a significant role in preventing and regulating the spread of the Covid-19 virus. Because of this, residential or office buildings have developed into the primary locations, as individuals are required to play a crucial role in preventing and

controlling the Covid-19 virus. The use of community- and building-based prevention and control measures concerning the safe use of public facilities and infrastructures are therefore the essential methods for combating the epidemic. These methods include building observation, community management, elevator disinfection, environmental cleaning, and other similar practices.

As defined by Yudelson (2009), the green building reflects and strives to reduce negative environmental and human health impacts. Since 2000, environmentally friendly building practices have taken over the construction industry. Commercial buildings have been at the forefront of this change, while office buildings have trailed behind. The sustainable design aims to increase occupant health and resource efficiency while reducing the built environment's impact on the natural ecological system. Green buildings are often recognized as eco-friendly structures (Kibert, 2004). As a result, there has been an increased emphasis on green building development throughout the last two decades, bringing a gradual trend toward green buildings. According to International Well Building Institute, WELL Building Standard 2014, building wellness is the process of enhancing a building's indoor environment by bringing the inhabitants' health and well-being to the centre of design and construction decisions, resulting in a designed environment that enhances nutrition, fitness, mood, and sleep patterns.

Assessment Standard for Green Building (GB/T 50379-2019) (ASBG) is China's most recent national standard for green building assessment. This standard emphasizes safety, health, and liveability on the fundamental environmental protection, which is beneficial to COVID-19 prevention and control (World Green Building Council, 2019). ASGB is committed to the practical path of being people-oriented, performance-based, and quality-improved as it works toward its goals of implementing the concept of green expansion and developing the idea of green buildings. Additionally, it takes into

consideration the safety, durability, health, liveability, and accessibility of all occupants, and it incorporates new technologies and concepts that are used in the creation of building technology.

Due to movement restriction orders and lockdowns in some areas, mobility-restricting travel behaviour impacts people worldwide (Dias *et al.*, 2021). Passenger transport demand has reduced due to government lockdowns and concerns about developing and spreading the virus while accessing mass transportation modes. Communities need to reclaim their shattered sense of safety when venturing out into the public by embracing the potential offered by public spaces and facilities and making better use of public areas for economic and social reasons (Christele Harrouk, 2021). The epidemic has highlighted deficiencies in public spaces that must be addressed: accessibility, adaptability, design, connectivity, and equitable distribution across a metropolis. These measures will aid in addressing severe health, safety, and economic security issues.

2.2 Green Building Technology in Construction Industry – Sustainable Development Goals (SDGs) (United Nations)

The Sustainable Development Goals (SDGs) have been established to ensure humanity's continuation. The multidimensional nature of sustainability necessitates multidisciplinary research initiatives for the SDGs. The 17 Sustainable Development Goals (SDGs) and their respective priorities are central to the United Nations (UN) 2030 Plan for Sustainable Development, endorsed by the 193 member states of the UN General Assembly in 2015. (United Nations, 2021). The SDGs are a new, universal set of goals, targets, and indicators that UN member states will use to guide their agendas and political actions over the next 15 years.

SDGs are proposed to implement the foundations of sustainable development with the objective of improving global health and well-being by facilitating the elimination of all forms of inequity and injustice, promoting climate change, quality education, gender equality, peace, and social justice, and the goals' objectives (ranging from five to twelve targets per goal) are stated clearly (United Nations, 2021). The adoption of the 2030 Agenda for Sustainable Development has produced several initiatives to evaluate nations based on composite indicators reflecting their progress towards achieving all SDGs or their technical specifications. Other stakeholders, such as businesses, academic institutions, and civil society organizations, must also provide direct support in order to accomplish the Sustainable Development Goals (SDGs).

According to MacNaughton et al. (2017), When controlling for annual wages, job category, and level of education, users and tenants of GBT-rated buildings scored 26.4 percent higher on cognitive function tests and experienced 30 percent fewer sick building symptoms compared to users and occupants of non-certified buildings. These outcomes were assumed to be partially explained by IEQ factors, such as thermal conditions and lighting, but the findings indicate that the benefits of GBT extend beyond measurable IEQ factors; occupants report better IEQ and fewer health problems in GBT-certified buildings than in non-certified buildings. In addition, green buildings have reduced VOC levels, formaldehyde, allergens, nitrogen dioxide, and particulate matter, all of which have negatively affected human health. (MacNaughton *et al.*, 2017).

The COVID-19 epidemic has presented cities with unprecedented challenges, including constraints on their health care, education, and safety systems and disparities affecting vulnerable groups. As cities shrink, many disadvantaged individuals have lost their means of life due to their employment in the informal economy, which offers unpredictable wages, limited savings, and no social security. Other adverse outcomes are

the disproportionate use of force to enforce lockdowns, non-transparent distribution of humanitarian equipment, internal migrants stranded in large cities, human rights violations, and disempowerment of vulnerable individuals. All levels of government will have the opportunity to establish more inclusive, balanced, resilient, and sustainable societies during the phase of pandemic recovery.

2.2.1 SDG-9: Industry, Innovation, and Infrastructure – Built Resilient Infrastructure, Promote Sustainable Industrialization, and Foster Innovation

The SDG-9 index is a comprehensive but foundational method of measuring the degree to which nations have industrialized while promoting social inclusion and minimizing natural resource use and environmental impacts.

The green building rating system supports a unified approach to design and recognizes the significance of building design features in enhancing sustainability. These characteristics include reduced energy usage, protected building sites, enhanced indoor environmental quality, the use of sustainable materials, and lower water consumption (Asdrubali *et al.*, 2015). The most noteworthy green building and project in Malaysia, as accredited by the Green Building Index (GBI), Green Real Estate (GreenRE), or the Leadership in Energy and Environmental Design (LEED).

COVID-19 has created opportunities for the transition to sustainability and for rethinking sustainability to create a more sustainable future in a range of research topics, including urban transport systems (Kanda and Kivimaa, 2020) and the transition to a more sustainable energy source (Kuzemko *et al.*, 2020). In addition, the COVID-19 virus will impact future sustainability. This pandemic emphasized the need for resilient

infrastructure and industries to withstand economic and environmental shocks. In addition, innovation and initiatives play a significant role in assisting policymakers in sustainability following the COVID-19 conference. To contribute to achieving Sustainable Development Goal 9, fresh insights into supporting innovation processes and research and development units in the real world for building resilient infrastructure and domestic technology development are necessary.

Green buildings must be constructed to be resilient and flexible in adapting to a changing climate. SDG 9 will entail overcoming resource restrictions, constructing and enhancing the capacities of developing nations, and finding creative approaches to addressing development difficulties.

2.2.2 SDG-11: Sustainable Cities and Communities – Make Cities Inclusive, Safe, Resilient and Sustainable

Buildings are the foundations of cities, and green buildings are therefore key to their long-term sustainability. Cities are especially susceptible to the effects of climate change and natural disasters due to their high population density, infrastructure, and economic activity. Building urban resilience is essential to preventing personal, social, and financial losses. Enhancing the sustainability of urbanization processes is vital to protecting the environment and reducing the effects of climate change and disaster risk.

The confinement of hundreds of millions of people to their homes due to COVID-19 has shown severe inadequacies in the housing sector and social inequities relating to the quality and comfort of dwellings and building services such as sanitation. Moreover, low-quality housing magnifies inequality by posing substantial concerns to security and

health are becoming more apparent, mainly through indoor air pollution and increased living expenses due to insufficient energy efficiency.

They are investing in developing public transportation to accelerate the transition toward mobility systems based on the accessibility. However, people's hesitation in employing mass transit for hygienic reasons offers new challenges for public transportation. Therefore, in addition to immediate hygiene and social distancing measures, long-term financial support and infrastructure spending could be targeted to increase capacity, reduce crowding, and rebuild the appeal of public transportation, especially given that ability is likely to be strained while social distancing controls are implemented.

As economic activity picks up slowly, there is an opportunity to reallocate road space and encourage active transport to create jobs, reduce emissions, improve resilience, and even boost public health. These goals can be accomplished by promoting active transportation and reallocating road space.

2.3 Technical Aspects in Adoption of Green Building Technology

The implementation of GBT aims toward the goal of ensuring the long-term viability of buildings and infrastructure via epidemics as well as throughout future construction. During this epidemic, anyone is strictly prohibited from entering crowded areas such as shopping malls. Nevertheless, when the world progresses towards an endemic phase, individuals will need to become acquainted with the new norm and figure out how to coexist with the virus. Consequently, new revolutionary construction solutions are required to relieve these restrictions. In order to create healthy structures, engineers, architects, designers, and other professionals working in the built environment

are exploring various social and spatial implications of the built environment.

2.3.1 Air Filters

Innovative technology is required for healthy buildings to increase fresh air ventilation and hence limit COVID-19 virus transmission (Tokazhanov *et al.*, 2020). The World Health Organization (WHO) recommends using the most effective air filtration to safeguard against infectious diseases (2020). Heating, ventilation, and air conditioning (HVAC) systems significantly prevent spreading of contagious diseases (Megahed and Ghoneim, 2021).

Controlling the airflows in micro spaces such as rooms is necessary in order to prevent them from colliding with the airflows in other micro areas. This is necessary because the inflow has a tendency to travel to different places, which could result in the spread of pollutants and viruses. This could be achieved through the use of ventilation system technologies that, once activated, bring a flow of fresh air from the building's exterior to its interior and are carried out by a ventilator. In addition, ventilation and air conditioning systems should be equipped with high-efficiency filters to minimize the spread of viruses and germs significantly.

The temperature of the room and the relative humidity are the following two criteria to consider since both factors have such an influence on the coronavirus. The Society of Heating, Air-Conditioning, and Sanitary Engineers (SHASE) of Japan recommended that the temperature inside be between 17 and 28 degrees Celsius, with a relative humidity of 40 to 60 percent (Zheng *et al.*, 2021)

The use of HEPA filters in the functioning of room air cleaners is proven to successfully decrease the spread of viruses (Balocco and Leoncini, 2020). It eliminates

pathogenic agents in the building by generating effective airflow patterns; the indoor air is dissolved close to its source. Numerous other goods on the market, such as the semi-absolute filter ePM1 95 percent (Buivydiene *et al.*, 2019), PM2.5 filter (Nor *et al.*, 2021), and photocatalytic oxidation (PCO) filter, can be utilized to enhance the filtering grade (Ginestet, 2005). Install HVAC systems in buildings equipped with UVGI to improve indoor air quality and limit the spread of infectious diseases (Navaratnam *et al.*, 2022).

Ultraviolet Germicidal Irradiation (UVGI) is a direct way to decrease airborne disease transmission (Megahed and Ghoneim, 2021). This method tends to be appropriate for reducing virus concentrations in large buildings by utilizing the intensity of UV light produced by humans. UVGI can offer substantial protection at a minimal cost, making it perfect for retrofitting older buildings. UVGI technology eliminates pathogens by generating an irradiation zone above the heads of the room's inhabitants (Storm *et al.*, 2020). A benefit of UVGI is that the UV field does not affect the individuals in the room. UVGI can also be put on walls and ceilings as part of custom-made fixtures. In addition, UVGI does not require the services of a specialized professional and may be quickly installed in existing structures and readily installed in existing facilities (Beggs and Avital, 2020).

2.3.2 Smart Technologies Application or Tools

In fostering community resilience, it is apparent that technology applications and tools such as card swiping, voice control, and facial recognition can be utilized to avoid or minimize contact with contaminated surfaces. Tokazhanov et al. (2020) also emphasized that automobile systems, voice and facial recognition, and other artificial

intelligence-based innovative technologies could assist in creating healthy and safe surroundings in our modern dwellings.

Presently, as the number of Covid-19 cases fluctuates, technology applications based on the Internet of Things (IoT) provide more significant benefits. The touchless and automated processes they enable can be beneficial during this worldwide health crisis. Furthermore, in support of social distancing practices, the application of this technology is essential for organizations with human-centered activities to maintain safe spaces, as this technology will reduce or eliminate the need to touch shared surfaces in order to prevent the spread of the Covid-19 virus.

Furthermore, an automatic disinfection system can perform contactless disinfection of the exterior surfaces to arrest further infection if one gets contaminated while moving or working. It will be an effective deterrence against the spread of infection (Maurya *et al.*, 2020). Applying ultraviolet (UV) disinfection technologies for bio-contaminated air and surfaces as the significant media for disease transmission is a potential system for public settings. Disinfection using UV radiation is highly efficient at controlling microbial growth in any medium, such as water and air, as well as on any surface (Raeiszadeh and Adeli, 2020).

2.3.3 Wall and Floor Treatments

A study by Cortes et al. (2020) highlighted the survivability of COVID-19 variants on surfaces varies depending on the material. Airborne viral stability and decay rates in copper, cardboard, stainless steel, and plastic were compared in a study. According to the findings, no SARS-CoV-2 virus residues were detected on the copper surface after four hours of testing. Meanwhile, the virus lasted for three days on plastic, two days on stainless steel, and one day on cardboard (Marzoli *et al.*, 2021). Using

copper-based building materials and components is expected to reduce the spread of infectious diseases. Contamination and infection transmission can be minimized using this metal in alloys on high-touch surfaces such as elevator buttons and door handles (Otter *et al.*, 2020). Viruses can also be slowed down by cardboard because of its porous texture (Brownell, 2020)

Another potential approach for preventing or reducing the number of germs on floors and walls is using antibacterial paints (Goss, 2021). Unfortunately, some species of mold, fungi, and bacteria are immune to particular paints. Nevertheless, antimicrobial characteristics in Biocote paint provide approximately 99 percent protection against the growth of germs, making it one of the most effective antimicrobial paints currently available (Rush, 2021)

Fabric wall coverings and upholstered panels are among the options recommended as alternatives to the more traditional commercial vinyl wall coverings (Otter *et al.*, 2020). Sanitary cladding is a system with enhanced hygienic properties since it is simple to clean, economical, and chemically resistant (Goss, 2021). Therefore, these items are suitable for wall treatments in buildings constructed after COVID-19. Essential properties of sanitary coatings and coverings include resistance to cold cracking, heat-aging, crocking, scrub ability, and chemical resistance.

2.4 Non-Technical Aspects in Adoption of Green Building Technology

The primary purpose of sustainable building implementation is to reduce the building's environmental and social impacts while simultaneously improving the quality of life for building inhabitants. The contemporary green building movements endorse a better facility with less construction waste, better building operation, and maintenance

through water and energy conservation, improved air quality, and a lifecycle perspective that includes recycling and deconstruction at the end of the building's life. However, the design of a building and its subsequent environmental performance may be influenced by occupant behaviors and may affect the prevention and control of COVID-19. Therefore, for future public health crises, the issue of how to prevent and control epidemics in buildings is a significant concern.

2.4.1 Prevention of Virus Propagation (PV)

The National Health Commission and the State Administration of Traditional Chinese Medicine have said that the fundamentals of COVID-19 prevention and management for inhabitants of public buildings (2020) include natural ventilation, interior disinfection, cleanliness, and the avoidance of gatherings. In addition, the management of waste, the dissemination of information, the administration of information, and the maintenance of building equipment are all instances of measures included in property administration.

The interior space of the building needs to be optimized to boost the effectiveness of natural ventilation and improve the air exchange rate. It is also recommended that buildings be designed to allow sufficient natural light to brighten certain regions. This is because radiation from the sun can destroy diseases and inhibit their activity (Alonso-Sáez *et al.*, 2006). In addition, it inhibits the growth of bacteria in building dust (Kline *et al.*, 2018).

As COVID-19 can spread through the air and on objects infected individual touches, adequate safety and social distance must be maintained. The architecture may

have included moving the furnishings for broader passageways to reduce crowdedness or placing glass walls as a barrier to divide the standard sections.

In addition, the building equipment system should have automatic monitoring and management functions in order to assist in the establishment of a healthier environment in residential buildings. This can be accomplished by reducing the amount of human participation, improving remote control, and lowering the risk of virus spread, which are desirable during a pandemic (Megahed and Ghoneim, 2020)

2.4.2 Building Management

Human-Building Interaction (HBI) is concerned with enhancing the interface between humans and buildings by studying building occupants and gaining an understanding of why and how building users interact with their settings (Park *et al.*, 2022). As a result of the COVID-19 pandemic, new HBI methods will be incorporated into building design, including voice-activated elevators, doors, water fountains, hands-free light switches, thermostats, and surfaces with antimicrobial textiles and finishes. In addition, buildings will be designed or retrofitted to operate more flexibly, such as by incorporating movable walls and partitions to reconfigure spatial arrangements to reduce the likelihood of infectious diseases or by redesigning spaces to ensure physical separation and restrict movement in congested areas (Awada *et al.*, 2021).

The system for managing building equipment must include automatic monitoring and management functions. The automatic monitoring management function enables the non-contact and remote management of construction equipment, simplifying the remote administration of construction equipment by the property management staff during the epidemic. Furthermore, the automatic control of essential equipment enables the

connection between the operation of construction equipment and the prevention and control of outbreaks (Wang *et al.*, 2020).

The building should also be equipped with an information network system. AI-based learning and controls, such as Adaptive Neuro-Fuzzy Inference System-based (ANFIS) and Artificial Neural Network (ANN) control, are used to analyze IEQ by connecting health and buildings (Kim and Katipamula, 2018). Further crucial use of AI is the proactive monitoring of building activities, such as fault, detection, diagnosis, and prognosis, in order to provide occupants with healthy environments (Rogers, Guo, and Rasmussen, 2019)

2.4.3 Indoor Space and Interior Design

In order to increase interior air quality, the spatial layout must be taken into consideration during building design. Spatial design is a conceptual design approach that accounts for both internal and service design. This requires the flow of people between interior and exterior environments (Chatzikonstantinou, 2016). In addition, biophilic design concepts are employed to improve indoor air quality by incorporating natural elements such as indoor plants, fresh air, and natural sounds (Det Udomsap and Hallinger, 2020). These indoor plants and natural sounds are frequently recommended for hospital interiors in order to accelerate patient recovery and minimize hospital stays (Awada *et al.*, 2021). Consequently, it is also reasonable to anticipate that maintaining a higher IEQ can be helpful against many infectious disorders caused by different viral types similar to the COVID-19 virus (Al horr *et al.*, 2016). The reorganization of the design layout also plays an essential role in the first-level response to public health emergencies.

The interior design of buildings should be conducive to personnel evacuation, emergency rescue, material transportation, etc. During the pandemic breakout, buildings and surrounding sites should provide rapid access to medical equipment and facilities, conduct adequate personnel and vehicle control, and change the room function when necessary to be used in virus prevention and control. An open, flexible, and variable space design can be adopted for the building functions. The passage spaces, such as corridors and evacuation passages, shall meet the requirements of emergency evacuation and rescue and shall be kept unblocked (Wang *et al.*, 2020).

CHAPTER 3

RESEARCH AND METHODOLOGY

3.1 Introduction

This research approach aims to provide a comprehensive literature evaluation of the meaning of green buildings in terms of safety, health, and livability and address the immediate needs for COVID-19 prevention and control, which is helpful to the disease's epidemiology. First, however, the necessity of a good understanding of green building to establish a comprehensive approach that assures the data's reliability and precision.

The literature review is valuable for understanding the hypothesis, data statistics, and research information. The current study's indicators focused on the scenario during the number of COVID-19 infection cases. On the other hand, this research will be undertaken when the limited activity order has gradually faded and the community has returned to normalcy.

The research methods for the study on implementing green building technology in controlling COVID-19 risk for public facility improvements will be presented in this chapter. A questionnaire survey will be used to collect the information. The surveys are provided to building managers and occupants of public facilities.

The acquired data were analyzed using Microsoft Excel, compiled, and presented in the form of tables, charts, and bars. Figure 3.1 illustrates the whole procedure of this research.

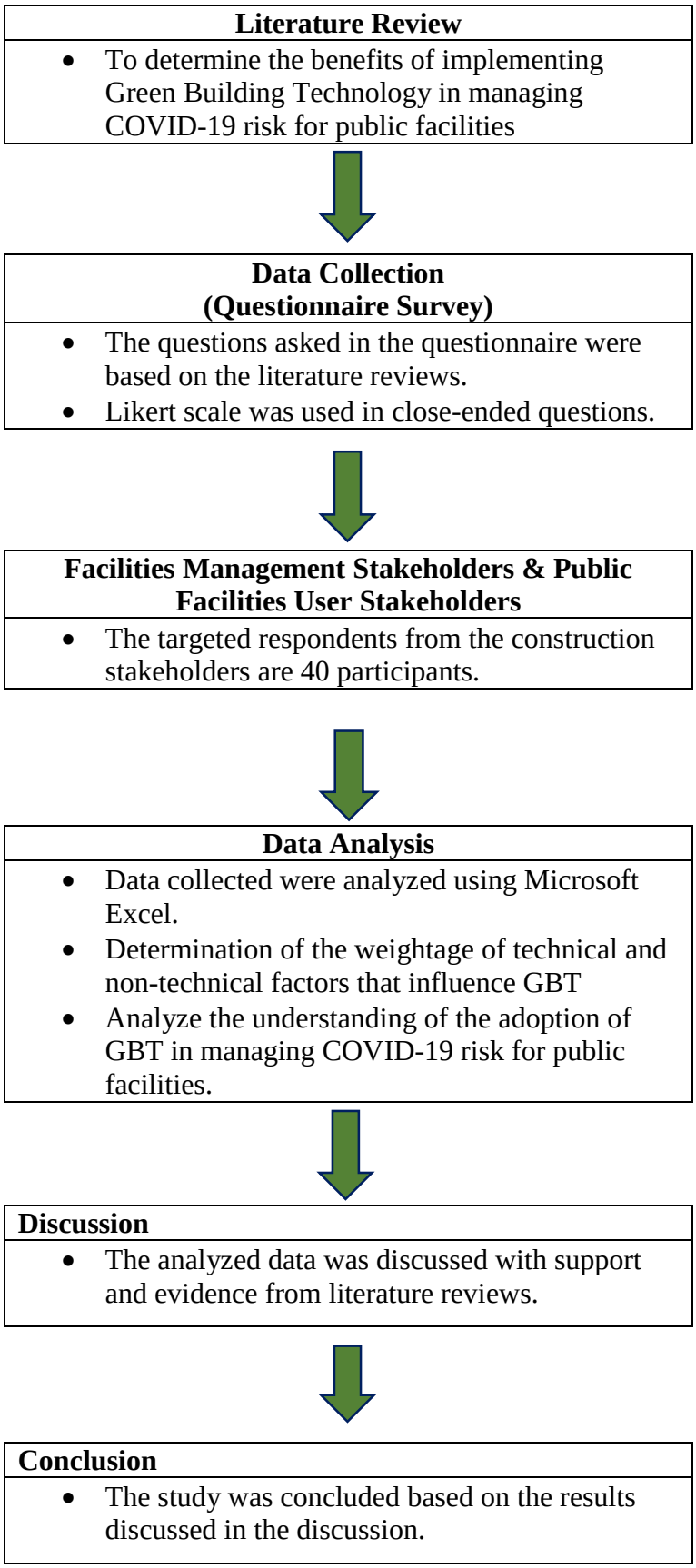

Figure 3.1: Flowchart of research methodology

3.2 Data Collection

Data collection is the systematic process of collecting and analyzing information in order to answer pertinent questions and evaluate the outcomes. It emphasizes understanding everything to learn about a particular topic. The purpose of collecting data is to undertake hypothesis testing, which is used to explain a phenomenon.

Primary and secondary data are the two types of data obtained. Primary data collection refers to the act of gathering unprocessed information directly from its point of origin. It refers to the process of a researcher compiling their unique data to complete a particular research endeavor.

On the other hand, secondary data collection refers to the gathering of data from a source other than the original user. For instance, it collects information from previously published books, periodicals, and websites. It is significantly less expensive and simpler to collect.

There are various reasons for collecting data, including maintaining the integrity of the study topic, reducing the chance of mistakes, minimizing the error of decision-making, and supporting the necessity for a new concept, change, or innovation.

3.3 Questionnaire Survey

A questionnaire is an appropriate study tool to collect opinions on knowledge on the adoption of Green Building Technology in managing COVID-19 risk for public facilities improvements. Questionnaires are a cost-efficient approach, can reach out and gain feedback quickly, have more considerable scalability of the audience, and are flexible for respondents where and when to complete the questionnaire.