



**JOURNAL OF TOURISM,
HOSPITALITY AND
ENVIRONMENT MANAGEMENT
(JTthem)**
www.jthem.com



**COVID-19 MITIGATION IN BUILT ENVIRONMENTS -
AVERTING CONTAMINATION AND REDUCING
PROLIFERATION OF VIRAL PANDEMICS**

Teo Kok Wei^{1*}, Mohd Shahril Abdul Rahman²

¹ Department of Real Estate, Faculty of Built Environment & Surveying, Johor Bahru, MALAYSIA
Email: tkw@graduate.utm.my

² Department of Real Estate, Faculty of Built Environment & Surveying, Johor Bahru, MALAYSIA
Email: mshahril.ar@utm.my

* Corresponding Author

Article Info:

Article history:

Received date: 15.12.2021

Revised date: 13.01.2022

Accepted date: 25.02.2022

Published date: 08.03.2022

To cite this document:

Teo, K. W., & Rahman, M. S. A (2022). Covid-19 Mitigation In Built Environments – Averting Contamination And Reducing Proliferation Of Viral Pandemics. *Journal of Tourism Hospitality and Environment Management*, 7 (27), 332-341.

DOI: 10.35631/JTthem.727026.

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Abstract:

The Covid-19 viral pandemic has spread to every corner of the globe, making it one of the greatest disasters in modern history. Stakeholders can avert virus contamination and reduce the proliferation of such pandemics through built environment mediated pathways which will benefit decision-making processes. This paper aims to present the challenges facing built environments, the improvements that can be made and technological advances available to study the approaches required to address the potential for contamination by pandemics such as Covid-19. A comprehensive and detailed review was done determine the challenges facing built environments during pandemics, subsequent improvements to built environments, and technological advances available was done. It was found that compliance to standard operating procedures and design limitations were challenges faced, improvements such as building reforms, post-pandemic office and home designs can be carried out, and technological advances such as construction strategy and digital transformation can be applied. Further research must be carried out as resources and literature pertaining to issues concerning Covid-19 in built environments is still in the infancy period.

Keywords:

Covid-19; Building Operations; Built Environment; Pandemic; Sustainability

Introduction

Background of the Study

Since humanity suffered in the 1970s due to herpes and legionnaires' disease, to AIDS and Ebola in the 1990s, the severe acute respiratory syndrome (SARS) in the 2000s, and most recently Covid-19, infectious diseases continue to threaten and disrupt humans (Jones, 2020). This terrible crisis faced by humanity, Covid-19, resulted in 276,436,619 confirmed cases and more than 5,374,744 deaths globally as of 23 December 2021, engulfing almost all countries across all continents, as shown in Figure 1 below (WHO, 2021).

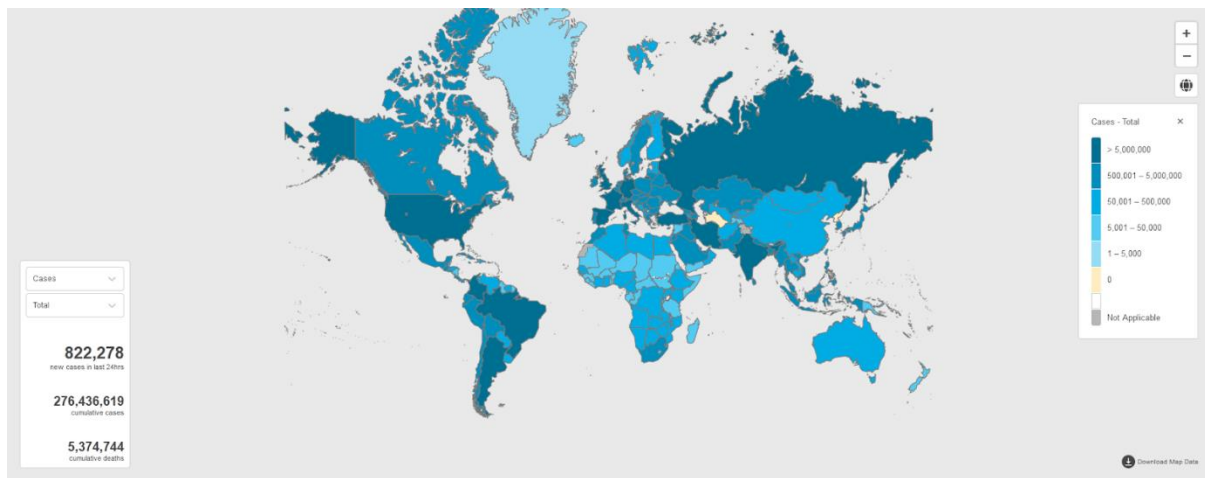


Figure 1: Global Covid-19 case heatmap as of 23 December 2021

Source: World Health Organisation (WHO), 2021.

Research Issues

The main research questions addressed are as follows:

RQ1: What are the challenges faced by built environments in the era of Covid-19?

RQ2: What are the improvements that can be made to address the contamination by pandemics such as Covid-19?

RQ3: What are the technological advances available to address Covid-19?

Gaps in Knowledge & Deficiency in Practices

This paper is crucial as the movement restrictions in urban areas due to the Covid-19 crisis had exposed the limitations and deficiencies of buildings and built environments. We must ask ourselves whether these lessons trigger the changes towards lower risks in urban areas and the creation of a more sustainable environment (Pinheiro & Luis, 2020). Adhering to strict guidelines and the movement control orders set by MOH Malaysia, extensive research of online articles and journals to avoid unnecessary face-to-face interactions and travel (MOH, 2021). Research into this field is still relatively new, as the Covid-19 pandemic had exacerbated the need for further research.



Figure 2: Statement on The Effect of Epidemics on Built Environments (Chang, 2020)

Aims Of Study

This paper aims to study the challenges facing built environments, the improvements that can be made and technological advances available to study the approaches required to address the potential for contamination by pandemics such as Covid-19, and finally summarising and synthesising the findings.

Purpose Of Study

The purpose of this study is to increase awareness among stakeholders with regards to the mitigation of Covid-19 and pandemics in built environments. Through that, the stakeholders may prepare some measures (policy making/regulatory amendments, etc.) on facing the challenges. A literature review study was conducted to fulfil the aims.

Objectives Of Study

The research objectives are listed as follows:

RO1: To determine the challenges faced by built environments in the era of Covid-19.

RO2: To determine the improvements that can be made to address the contamination by pandemics such as Covid-19.

RO3: To determine the technological advances available to address Covid-19.

List of Remaining Subtopics

The lists of remaining subtopics according to the sequence are the methodology, literature review, conclusion, and references.

Methodology

A comprehensive and detailed search for the publications related to determine the challenges facing built environments during pandemics, subsequent improvements to built environments, and technological advances available was carried out. The databases were obtained from Google Scholar, online journal resources such as Emerald, US National Library of Medicine, ScienceDirect Journals, Scopus, and MDPI to name a few. The publications contained various literatures and information to determine the challenges, improvements, and technological advances. The keywords used for article searching are: Covid-19; Building Operations; Built Environment; Pandemic; Sustainability.

After a thorough review of 68 scholarly articles, literature with redundancy, unrelated contents deemed not suitable were filtered out. Altogether there were a total of 15 articles related to the topic. The information for this paper was extracted from those articles which generated the factors of Covid-19, post-pandemic and pre-pandemic built environments, digital and technological transformations, risk control measures, challenges facing built environments,

improvements to built environments, and technological advances are studied. A content analysis was done and a literature matrix constructed in Table 1 as follows:

Table 1: Literature Review (L.R.) Matrix

L.R.	Literature Areas	Sources
3.1	Challenges Facing Built Environments	
3.1.1	*Compliance To Standard Operating Procedures	<i>Budds, 2020; Ministry of Health Malaysia (MOH), 2021; World Health Organisation (WHO), 2021.</i>
3.1.2	*Design Limitations	<i>Chang, 2020; Dietz et. al., 2020;(Goniewicz et al., 202); Saadat et al., 2020; Salama, 2020.</i>
3.2	Improvements To Built Environments	
3.2.1	*Building Reforms	<i>Budds, 2020; Chang V., 2020; Dietz et. al., 2020.</i>
3.2.2	*Post-Pandemic Homes	<i>Molla, 2020; Wainwright, 2020.</i>
3.2.3	*Post-Pandemic Office Spaces	<i>Pinheiro & Luis, 2020.</i>
3.3	Technological Advances	
3.3.1	*Construction Strategy	<i>Saadat et.al., 2020.</i>
3.3.2	*Digital Transformation	<i>Molla, 2020; Megahed & Ghoneim, 2020.</i>

Literature Review

Challenges Facing Built Environments

Compliance to standard operating procedures and design limitations are two of the main challenges facing built environments in the new normal.

Compliance To Standard Operating Procedures

Physical distancing could change the design and planning process (Budds, 2020), specifically with the increased acceptance of distance learning, online shopping, and online entertainment. MOH Malaysia has prescribed maintaining physical distancing of 1.0 meters, avoiding crowded places and usage of alcohol-based hand sanitisers (MOH, 2021), as shown in Figure 3 below to mitigate the spread of Covid-19. The additional implementation of temperature scanners and personal hygiene procedures have continuously been highlighted by WHO, who are updating guidelines based on the latest information and researches by professionals (WHO, 2021).



Figure 3: Various Infographics Which are Common in The New Normal

Source: Ministry Of Health Malaysia (MOH), 2021.

Design Limitations

Covid-19 had propelled authorities to restrict access to most public spaces and large areas, which could change the way they operate. Architects, planners, and built environment professionals are keen to examine many social and spatial implications to generate new patterns and configurations of use (Salama, 2020). Most architecture today shows evidence of how humans have responded to infectious diseases by redesigning our physical spaces to prevent Covid-19 deposition, as shown in Figure 4 below. Working from remote locations, learning online and shopping from e-commerce sites drives the focus on virtual access from smart devices (Goniewicz et al., 2020). Certain densely populated cities are vulnerable to the risk of infection (Chang, 2020). Working from home reduces physical contact but might pose a challenge for smaller and crowded houses without outside spaces (Saadat et al., 2020).



Figure 4: Conceptualization of Covid-19 deposition

(a) Viral particles accumulate in the lungs and upper respiratory tract of the infected person.
 (b) Droplets and aerosolized viral particles are expelled through coughing and talking, which spreads to nearby surroundings and individuals. (c and d) Viral particles are often found on hands (c) and can spread to touched items (d) such as computers and countertops

Source: Dietz et al., 2020.

Improvements To Built Environments

Various improvements and designs including urban renewal, sanitary infrastructure and building reforms reduces the risk posed by infectious diseases. These improvements had been the result of many trials and errors which have been fine-tuned by people centuries ago.

Building Reforms

In the 14th century, the bubonic plague motivated the fundamental urban improvements of the Renaissance. Overcrowded living quarters shuttered down, margins expanded, early quarantine facilities developed, and large public spaces opened. In the 20th century, infectious diseases were one of the drivers of urban renewal which includes urban planning, slum clearance, and waste management (Chang, 2020).

During the industrial era, cholera and typhoid influenced the sanitary reform movement. Water and sewerage systems development eventually led to sanitary innovation and created straighter, smoother, and wider roads for installation of underground pipe systems. Furthermore, the bubonic plague pandemic in 1855 changed the design of drain pipes to door thresholds and building foundations (Budds, 2020).

The wipe-clean design of modernist architecture is partially attributed to tuberculosis, inspired by purity of form, strict geometries and modern materials. Beyond aesthetics, the healing effects of light, air, and nature led to the design of large windows, balconies, flat surfaces that would not collect dust, and white paint projected cleanliness and tidiness (Chang, 2020). The understanding of the spatial relationship between common room and door settings in built environments can be further clarified in Figure 5 on the next page:

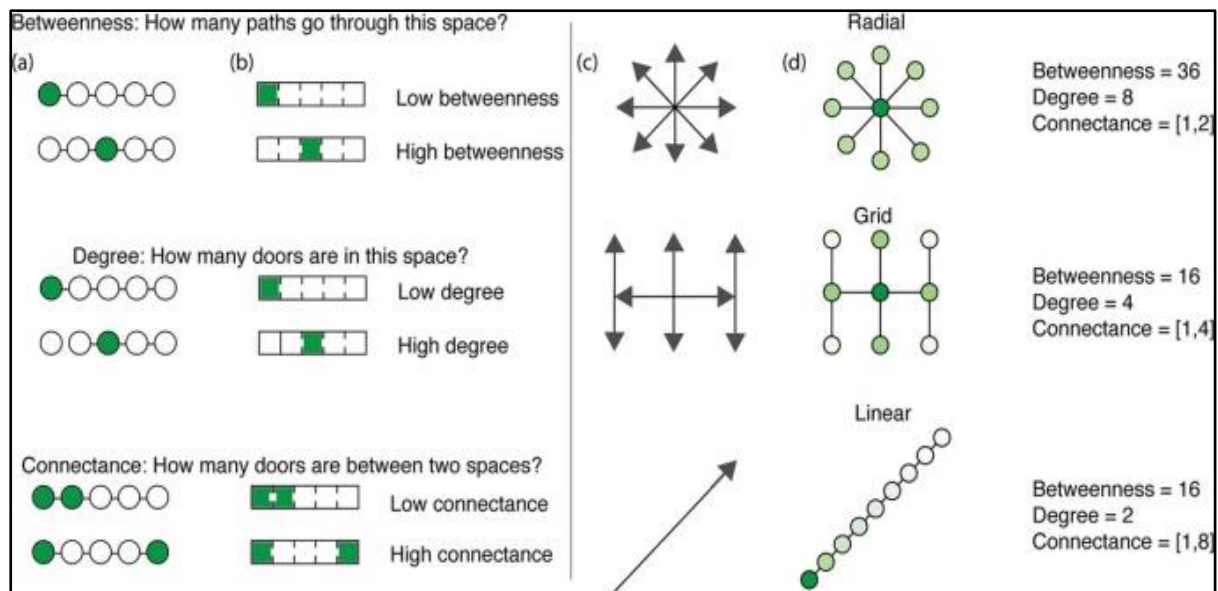


Figure 5: Spatial Relations: Common Room and Door Settings

(a) Circles and lines follow the classic network representation.

(b) The rectangles follow the architectural translation of networks. Shaded areas correspond to a measure of betweenness (the number of shortest paths between all pairs of spaces that pass through a given space over the sum of all shortest paths between all pairs of spaces in the building), degree (the number of connections a space has to other spaces between any two spaces), and connectance (total doors between any two spaces).

(c) *The arrows represent possible directions of microbial spread as determined by the layout of the built environment.*

(d) *The circles represent the current knowledge of microbial spread based on microbial abundance through built environments as determined by layout. Darker colors show higher microbial abundance, and lighter colors represent lower microbial abundance.*

Source: Dietz et al., 2020.

From Figure 5, a basis of understanding of post-pandemic homes and office spaces as compared to the contemporary design has been identified, which will be further discussed next.

Post-Pandemic Homes

The pandemic has brought a greater sense of appreciation for houses that can effectively provide social isolation and protection from viruses and infections. Several researches proved a direct link between crowding and adverse health effects. In multi-story buildings, contact with other residents in shared areas is largely unavoidable. The future should, therefore, focus on the touchless experience from the front door to the apartment door itself (Molla, 2020) as more people will spend time and work at home, as well as to reduce contact with surfaces.

With regards to the layout and design solutions, post-pandemic housing might introduce more partitions between departments and could be the end of open-plan spaces. The building might have wider corridors and doorways, and more staircases, leading to changes in the building code and design strategies. Ensuring flexible and adaptable spaces for all users can make housing more sustainable, able to adapt to changing needs and evolving lifestyles (Wainwright, 2020).

Post-Pandemic Office Spaces

As remote working becomes the new norm, office space must accommodate greater spacing and fewer seating options. Firms that were initially resistant to the remote working concept have been receptive to allow work from home to reduce the risk of contact. Thus, office densities will change and less space will be utilised for work from home policies. This is hastening the shift from structured office environments to more flexible, virtual, and home-based work environments, reversing the open-office trend and boosting the search for better natural ventilation and healthy design options. Consequently, high-rise buildings would be more expensive to build and become less efficient. Ultraviolet germicidal irradiation can be used to disinfect offices at night or meeting rooms between uses (Pinheiro & Luis, 2020).

Technological Advances

To receive the maximum benefits from the previous approaches, technological advances such as construction strategy and digital transformation ensures that the transition towards pandemic-proof built environments becomes a success.

Construction Strategy

Special concerted efforts to consider and think about every possible place within the built environment touched by people and the possibility of that being a source of infections is essential. Like the modernists who rejected ornamentation in favour of hygiene, contemporary designers use hygienic and anti-bacterial materials that are easily sanitized. Post-pandemic architecture might implement more cleaning strategies based on newer and modern technologies. Buildings critically designed with rooftop terraces, balconies, skylights, big

windows, and courtyards will prevent the sick-building syndrome and enhance the air quality (Saadat et.al., 2020) which subsequently reduce the impact of viruses.

Digital Transformation

The global pandemic has amplified digital transformation in all our activities, including artificial intelligence and touchless technologies such as automation, voice technology, and facial recognition. Touchless technology could become a new interface by removing the requirement for physically pushing or touching a surface which serves as a conduit for 80% of viral transmissions (Megahed & Ghoneim, 2020). For example, calling lifts via a smartphone, avoiding the need to press any buttons, and doors opening automatically upon detection of movement. These technologies can be integrated into future building designs to control space temperature and automatically clean surfaces to kill harmful organisms, viruses, and bacteria. Albeit at an added cost, it might popularize over time (Molla, 2020).

Summary Of Findings

A summary of the findings is presented in Table 2:

Table 2: Summary of Findings

Research Questions	Findings
What are the challenges faced by built environments in the era of Covid-19?	Compliance to standard operating procedures and design limitations are two of the main challenges facing built environments in the new normal.
What are the improvements that can be made to address the contamination by pandemics such as Covid-19?	Various improvements and designs including urban renewal, sanitary infrastructure and building reforms reduces the risk posed by infectious diseases. These improvements had been the result of many trials and errors which have been fine-tuned by people centuries ago.
What are the technological advances available to address Covid-19?	To receive the maximum benefits from the previous approaches, technological advances such as construction strategy and digital transformation ensures that the transition towards pandemic-proof built environments becomes a success.

Conclusion

This paper links the various pandemic challenges and highlights the changes caused in built environments. The global pandemic has taught us how to manage our built environment through design, build, and operations. It is no longer safe to solely rely on a strategy to protect our architecture and urbanism. Instead, we must incorporate a multi-layered approach of protection into the built environment defence system. New technologies have created opportunities to apply innovative solutions to smart and virtual applications in the built environment. This study presents insights for areas where future research will be critically required. Based on the lessons learned from this crisis, this study introduces a vision to stop the spread of the virus or to mitigate its impacts. In this context, the pandemic increased the need for policymakers, planners, and architects to think more out of the box, trying to reshape

our physical spaces, and reset the existing build environment or develop more ideas to face future virus attacks and not wait for another pandemic to serve as a reminder. The current health crisis should trigger the further development of our built environment to increase the security layers that help to prevent the spread of infections and diseases. We must accept that life after the pandemic will never be the same. Many measures adopted during these times of emergency will become part of daily life, changing our regular habits and behaviours through positive or negative intervention in architecture and urban planning approaches. The right design and planning strategies could help to position our built environment in the post-pandemic era. There are many other social effects beyond the pandemic; however, the long-term impact is unclear, requiring further studies and research. **Proposed topics for further studies include the role of built environments in preventing contamination; Sustainable built environments in times of pandemics, as well as Technology and IOT for built environments to face the Covid-19 threat.** At least we can understand the risks and be better prepared in the prevention and quickly react in mitigation action. Proactive, not reactive action will continue to update this antivirus-enabled paradigm and install new approaches within its framework. **There is no end in sight to the COVID-19 pandemic, but it has helped us predict what post-pandemic architecture and urbanism might look like.**

Acknowledgement

The authors would like to thank the Ministry of Higher Education Malaysia (MoHE) and Universiti Teknologi Malaysia for the support (Fundamental Research Grant Scheme - FRGS/1/2019/SS08/UTM/02/8)

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