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The Preventive Indicators for Evaluating the Design of Existing Buildings as Epidemic-Resilient Architecture: A Theoretical Framework

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Abstract

The recent outbreak of epidemics created health challenges and emerging requirements that revealed weaknesses and increased alerts about the contribution of the existing buildings' design to increasing the possibility of epidemics' spread. Those risks necessitated focusing on designing more effectively resilient buildings to epidemics. The study focuses on improving the safety aspects of existing building design from an architectural design perspective. Therefore, this study proposes a theoretical framework for a set of preventive indicators to evaluate the existing building design as a resilient architectural system in its response to epidemics. These indicators have been identified and selected based on an extensive examination of the literature and the most effective practices for preventing and controlling epidemics. Those preventive indicators covered all the various aspects of the design of the existing building, including the effectiveness of social distancing, indoor air quality, indoor environmental quality, control engineering and preventive. Using these indicators, architecture professionals and policymakers can evaluate the effectiveness of existing buildings in reducing the spread of epidemics and making the necessary improvements to create a more resilient environment. The proposed preventive indicators aim to contribute to developing epidemic-resilient architecture and promote the creation of healthier and safer living environments for occupants.

Keywords: architectural design; epidemics; building design; preventive indicators; resilience.

Introduction

The recent outbreak of pandemics has led to significant and influential changes at many levels affecting human life (Sharma and Borah, 2022). These changes have reflected the architecture and architectural design (Alhusban et al., 2022). The forced experience of pandemic outbreaks has raised many questions and perspectives on building design and how to improve them to adapt towards epidemic resistance to ensure the continuity of the building's use (Güzelci et al., 2020; Salama, 2020). Furthermore, the outbreak of epidemics led to some concerns and alerts regarding the design of buildings and their role in exacerbating the transmission of infection between occupants (Fezi, 2020). Of course, all these indicators that relate to abnormal conditions point to the urgent need to build a more effective and innovative approach to overcoming the health risks that hinder users (Megahed and Ghoneim, 2020).

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Considering that most people spend more time inside than anywhere else (Matz et al., 2015), Buildings are a virus-incubating environment that controls the probability of transmission, consisting of various factors and types for the transmission. These factors include the indoor air, equipment and tools, common surfaces, space elements, kinetic performance and solid waste (Dietz et al., 2020). The infection can be transmitted by indoor air or direct-indirect physical contact. Therefore, the interaction between these ingredients and the availability of appropriate conditions ultimately leads to infection and spread between occupants when they use buildings (Priyanka et al., 2020).

Architecture has emerged today as a clear guide to changing social lifestyles due to pandemic outbreaks (Gür, 2022). For example, compliance with social distancing has led to a reconsideration of the design and organization of architectural spaces to adapt to epidemic-affected lifestyles (Chick et al., 2020). This lifestyle may persist and change an individual's habits and behaviours into emerging needs and requirements and may become a positive or negative transformation in the architectural design approaches (Alhusban et al., 2022).

The health challenges and requirements arising from the recent outbreak of epidemics have exposed design problems in existing buildings (Megahed and Ghoneim, 2020; Peters and Halleran, 2020). The need to overcome these challenges requires that architecture professionals play a role in reviewing past design concepts and strategies and evaluating the effectiveness of existing buildings' design and their ability to resist epidemics from an architectural perspective. From the preceding, the importance of studying the relationship between the existing building's design and the user's protection against the risks of epidemics. Therefore, the study focuses on improving the safety aspects of existing building design from an architectural design perspective, towards developing a guideline for policymakers and highlighting the architect's role in reducing the spread of epidemics. Thus, the current study seeks to answer the central research question: What essential preventive indicators can be used to evaluate the existing buildings' design as epidemic-resilient architecture? More specifically, this study aims to build a theoretical framework that determines preventive indicators that can be used in evaluating the design of existing buildings in terms of their ability to reduce the spread of epidemics.

Literature Review

During the search for previous studies, it was noted that there was great interest and intense publishing by specialists, indicating the importance of this area of research. Yet, there were more than (9000) studies, but less than (1%) of them were associated with architecture in any way. Architectural and urban articles relevant to the research topic were identified according to the search protocol, as shown in Table 1. A network visualization diagram was created using (VOSviewer) software to understand the research direction and identify the research problem. It was found that most of the search topics were focused on the keywords "COVID-19" and "BUILDING", as shown in Fig. 1, while other fields were not the primary focus in previous studies.

It was also noted that the previous literature was distinguished by its different research methods and the diversity of information and knowledge contributions presented. The most prominent current aspects dealt with by this previous literature can be summarized as shown in Table 2. In general, some studies focused on the role of architectural design in the fight

Table 1

The protocol used in the research process for this review (Source: Authors)

Year	Sources	Search Keywords
2020-2023	Scopus, ScienceDirect, Web of Science and Google Scholar	("Epidemic-Resilient Architecture" OR "Sustainable Architecture" OR "Healthy Architecture" OR "Architectural Design" OR "Buildings" OR "Building Design" OR "Built Environment" OR "Interior Design" OR "Architectural Spaces" OR "Interior Spaces" OR "External Spaces") AND ("COVID-19" OR "Pandemic" OR "Outbreaks of Epidemics" OR "Social Distancing" OR "Preventive Measures")

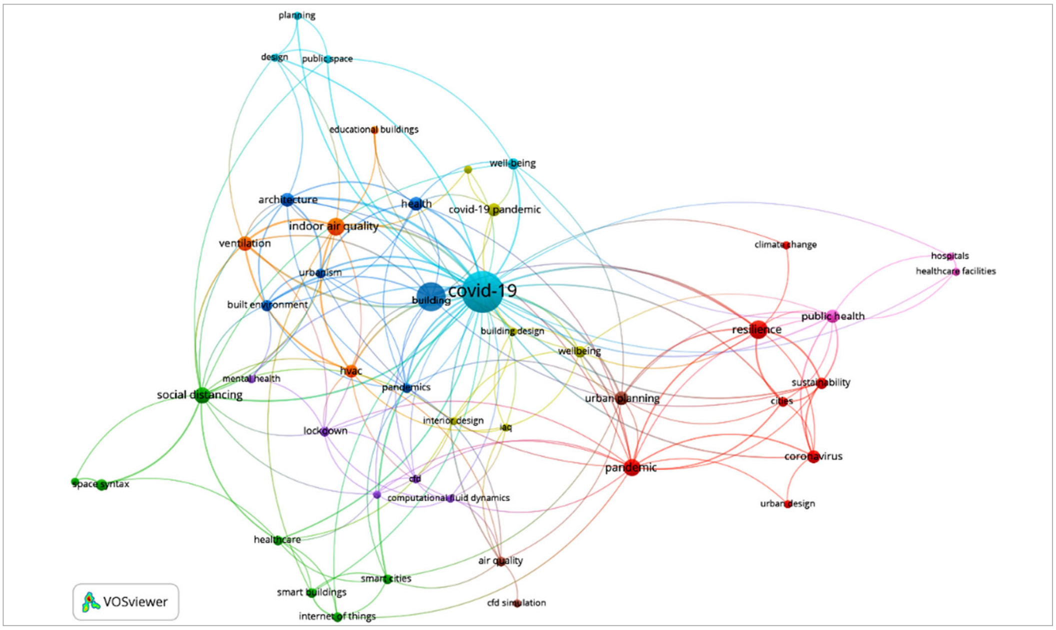

Fig. 1

Network visualization based on keyword co-occurrence analysis (Source: Authors using VOSviewer software. Note: the larger circles represent the largest area of search performed between search index dates)

against epidemics in the form of comparative analysis and discussions of some aspects of architecture that contribute to epidemic-resilient (Alhusban et al., 2022; Andrei Fezi, 2021; Fezi, 2020; Megahed and Ghoneim, 2020; Salama, 2020). At the same time, others focused on identifying preventive strategies and linking dimensions to sustainable development and epidemic outbreaks (Emmanuel et al., 2020; Pinheiro and Luís, 2020; Tleuken et al., 2021). However, some studies focused on technological aspects and emphasized the importance of environmental elements, assessing current realities for a specific type of public buildings and giving appropriate solutions (Hassan and Megahed, 2021; Navaratnam et al., 2022; Waheeb and Hemeida, 2022).

Table 2

A summary table of the most prominent current aspects dealt with in previous literature (Source: Authors)

Current Aspects			Literature
Epidemic Resilient Architecture Strategies	Physical strategies	Urban strategies	(Grigoriadou, 2020). (Majewska et al., 2022), (Maturana et al., 2021), (Megahed and Abdel-Kader, 2022), (Megahed and Ghoneim, 2020), (Mouratidis, 2022), (Peters and Halleran, 2020), (Pinheiro and Luís, 2020).
		Architectural strategies	(Al horr et al., 2016), (Alhusban et al., 2022), (Andrei Fezi, 2021), (Dietz et al., 2020), (Emmanuel et al., 2020), (Megahed and Ghoneim, 2020), (Navaratnam et al., 2022), (Peters and Halleran, 2020), (Pinheiro and Luís, 2020), (Salman and Hameed, 2021a), (Tleuken et al., 2021), (Ugail et al., 2021), (Younis, 2021).
	Technology Strategies		(Chick et al., 2020), (Elabd et al., 2021), (Mihalis, 2020).
Epidemic Resilient Architecture Features	Resilience	Transformation	(Chick et al., 2020), (Megahed and Ghoneim, 2020).
		Mobility	(Azuma et al., 2020), (Megahed and Ghoneim, 2020).
		Adaptation	(Alhusban et al., 2022), (Güzelci et al., 2020).
	Responsive		(Alhusban et al., 2022), (Hariyani and Pratama, 2021).
Epidemic Resilient Architecture Standards	Ventilation system standards		(Alkhalaf et al., 2023),(Asim et al., 2021), (Chen et al., 2022), (Hassan et al., 2020), (Megahed and Ghoneim, 2021).
	Access considerations		(Abdul Nasir et al., 2021), (Cristani et al., 2020), (M. Hameed Al-Delfi and S. Salman, 2022), (Mustafa and Ahmed, 2022).
	Space Requirements		(Al horr et al., 2016), (Asim et al., 2021),(Chen et al., 2022), (Morganti et al., 2022), (Younis, 2021).

There are more specialized studies conducted to study the relationship of the spatial configuration towards defining guidelines and spatial priorities to improve the social distance's efficacy (Abdul Nasir et al., 2021; M. Hameed Al-Delfi and S. Salman, 2022; Mustafa and Ahmed, 2022). In addition, other studies of this category have contributed to identifying some controls and engineering standards to reduce the possibility of transmitting pathogens through indoor air (Alkhalaf et al., 2023; Chen et al., 2022; Megahed and Ghoneim, 2021; Morawska et al., 2020). Other studies have also addressed the indoor environmental quality indicator and its role in reducing the spread of epidemics through the natural lighting element and other variables related to improving the design of healthy environments that will enhance the well-being and health of occupants (Al horr et al., 2016; Chen et al., 2022). As for the control and prevention engineering indicator, other studies focused on aspects of appropriate selection of interior materials in space design and self-cleaning of spaces (Navaratnam et al., 2022; Tleuken et al., 2021).

Finally, it can be argued that the previous literature included extensive and varied information. Still, there was no architectural study specialized in identifying the preventive indicators that can be used in evaluating existing buildings. Therefore, the research problem can be identified by the lack of a clear vision of preventive indicators for evaluating the design of existing buildings in terms of epidemic resilience.

Material and Methods

In trying to answer the research question and achieve the research objective, the methodology used begins, as shown in Fig. 2, by providing an overview of architectural design and epidemics. And then discuss infections and transmission methods to understand the most important sources and factors of transmission of infections. After that, the most important theories, supportive approaches and effective systems are addressed. The most important features that can be incorporated and invested in supporting the achievement of architectural Resilient to epidemics are discussed (Sect. 4). Then this follows the identification, classification and discussion of preventive indicators within the framework proposed by the research (Sect. 5).

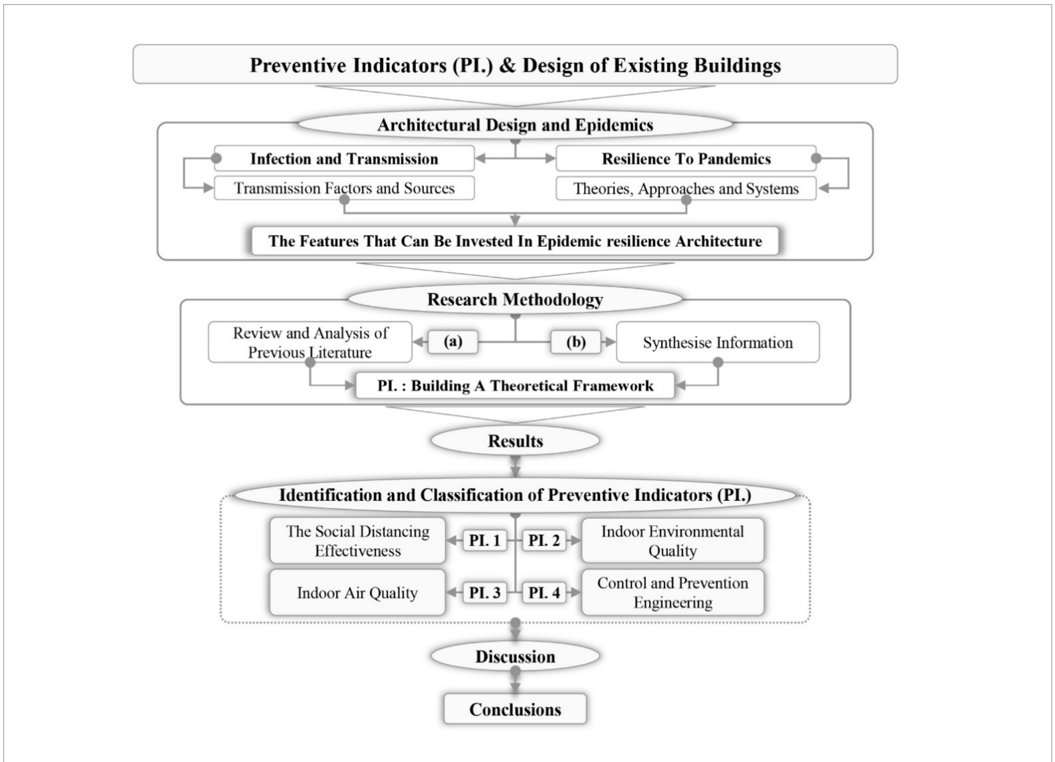

Fig. 2

A diagram of research methodology (Source: Authors)

The identification and classification of preventive indicators were achieved through two steps: (a) review and analysis of previous literature; and (b) the authors' discussion of the round table with creative brainstorming activities to synthesize information. Reviewing the previous literature covered all available sources of recent information. The previous literature included scientific papers, such as articles, and the applied practices represented in several practical studies, such as reports and blogs, with the practical and illustrative side of many different architectural aspects related to the architecture resilient to epidemics. Various resources were used according to a keyword-specific search, as shown in Table 1. After a review of the literature, brainstorming activities were conducted to identify critical preventive indicators within a theoretical framework. As a result, four main categories of indicators have been identified. They are divided into nine sub-categories with (66) Preventive solutions. Abbreviation and numbering were used to represent preventive indicators and distinguish between main categories (e.g., The Social Distancing Effectiveness (PI.1)) and Sub-categories (e.g., The Universal Design of Outdoor Spaces (PI.1.1)).

Overview of Architectural Design and Epidemics

It all started after the COVID-19 pandemic first emerged in December 2019 after the pandemic spread worldwide (CDC, 2021). A global public health emergency (WHO) declared COVID-19 a pandemic (global epidemic or disease that has infected all countries of the world) on 11 March (2020), while describing the coronavirus as a major threat to human life (WHO, 2020). Epidemics have led to significant changes at all levels, including architecture. They have revealed some weaknesses in the design of existing buildings. Accordingly, there are some concerns and alerts about the effectiveness of current design strategies. Therefore, an urgent need is to build a more modern, inclusive and innovative approach to this phenomenon through architecture (Salama, 2020).

The historical approach to architecture's role in the face of pandemic outbreaks significantly impacts design and architectural planning (Andrei Fezi, 2021). The architectural design followed the fear of infection just as it followed the function (Dear and Flusty, 1998, p. 36). The risks of epidemics have inspired many architects to design healthy, hygiene-oriented living environments (Campbell, 2005). For example, when the White Plague epidemic emerged in the nineteenth century, specialists identified that therapeutic environmental factors for tuberculosis were sunlight and fresh air. This led to a rethink of building design by architects, such as Lee Corbusier, who designed his work by focusing on some design elements such as purposeful balconies, smooth surfaces and elevated masses of the Earth and investing aspects of natural systems. To benefit from sunlight and fresh air that helps heal people from diseases (Campbell, 2005; Pinheiro and Luís, 2020).

Architectural response to the impact of epidemics can be considered a healthy and sustainable design strategy in architectural design that acts as an epidemic preventative due to an interaction between epidemic risks and the building's ability to reduce and mitigate the spread of epidemics. This strategy aims to align the continuity of use (the balance between architecture and Humans as a user) with the need to prevent the risk of epidemic spread as a humanitarian need (Megahed and Ghoneim, 2020; Tleuken et al., 2021). The term "indicators" has been developed to measure, monitor and evaluate a particular issue related to the building design, as with sustainability. The indicators have been used individually or composite to determine the extent to which the building achieves sustainability. The indicator provides valuable information about a physical, social or economic system to measure a complex phenomenon to examine the extent to which a particular policy's purpose has been achieved (Farrell and Hart, 1998).

Infection and Transmission in The Internal Environment of Buildings

Considering that most people spend more time inside than anywhere else (Matz et al., 2015), It is necessary to understand the transmission process. The primary sources of transmission of COVID-19 in the built environment have been identified through a host (Incubator of the virus) and from human to human, and there are other assurances that the built environment, including buildings, is also a medium for transmission (Azuma et al., 2020). The University of Oxford's Manual on Infection Prevention and Control (2019) outlined three main components of infection in the built environment: First: virus capable of producing infection (source of infection); Second: The host who is exposed to infection (incubator of the virus); Third: Suitable environment for virus reproduction (intermediate for transmission) (Damani, 2019, p. 7).

The interaction between these three ingredients and the provision of appropriate conditions ultimately leads to infection and spread between the occupants. Buildings are a virus-incubating environment and contribute to controlling the probability of transmission. They consist of a range of factors that are effective transmission mediums. These factors are Indoor air, water, contaminated food, equipment and tools common to users, common surfaces, space elements (furniture and doors), motor performance (convergence and physical contact between users), as well as solid waste (Dietz et al., 2020). As for transmission dynamics, an infection can be transmitted in the following ways (Hu et al., 2021; Priyanka et al., 2020):

1. Airborne infections (viral accumulations stuck in the air).
2. Contact Infection: Direct method: Direct physical contact between users (hands) / Indirect method: physical contact with surfaces and contaminated materials (common tools and objects).

Recent and specialized investigations have shown that people are more susceptible to infections transmitted through indoor air, especially in crowded and cramped areas with poor indoor ventilation (Megahed and Ghoneim, 2021). When people move, there is direct and indirect contact with the surfaces and common materials around them within the building spaces (Dietz et al., 2020). These viral accumulations stuck in the air can deposit and settle on nearby materials and surfaces. Whenever someone makes contact with the surface of what, viral exchange occurs from surface to individual and vice versa (Hu et al., 2021), as shown in **Fig. 3**. Thus, various environmental, functional and design factors engage and control transmission and spread among occupants while posing architectural challenges that reveal many weaknesses in the design of existing buildings.

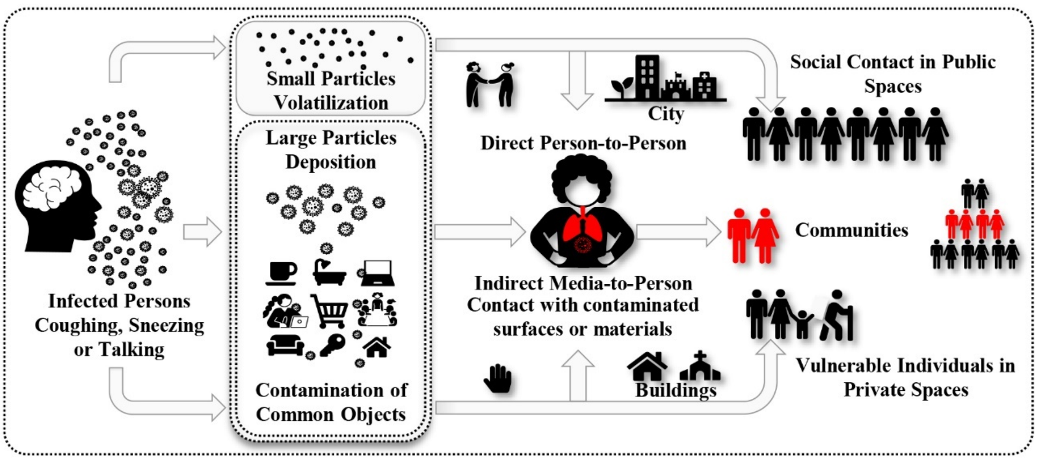

Fig. 3

Diagram showing the methods and factors of transmission of infection (Source: Authors, adapted from Hu et al., 2021)

Resilience To Pandemics: Integrating Theories, Approaches and Systems

Pandemic outbreaks pose significant challenges to the architectural design of existing buildings and their space functions. Epidemic-resilient architecture emerges as a statute focused on integrating different theories, approaches and systems to create spaces that can respond effectively and adapt to reduce the spread of epidemics. This section explores the multifaceted aspects of pandemic-resilient architecture by examining the integration of architectural theories, design approaches, and adaptive systems to promote healthier, safer, and more sustainable environments.

Integrating Theories, Approaches

To create spaces prioritizing healthy design, it is crucial to integrate the theoretical basis for architectural design, as highlighted in this paragraph. This is done by studying various architectural theories and adaptive systems to identify the most notable features that can be included in the architectural design of buildings, as shown in Table 3.

Table 3

A summary table of the features extracted from the most prominent architectural theories and design approaches (Source: Authors)

Theories And Approaches		Description	Features
(a)	Biophilic Design Theory	Biophilic design is one of the most central theses on human health and natural concepts. This type of design seeks to integrate elements of nature with a design based on the idea that humans have an innate need to communicate with nature and that this connection can be helpful in terms of offering comfort and a sense of well-being, as well as promoting mental and physical health (Browning et al., 2014).	_ Ventilation and natural lighting (Waheeb and Hemeida, 2022). _ Open spaces give users more space to spread (Yaseen and Mustafa, 2023). _ Using natural materials and barriers (Navaratnam et al., 2022).
(b)	Attention Recovery Theory (ART)	Established and developed by Rachel and Stephen Kaplan at the end of the 1980s, this theory is based on the idea that people are more likely to be alert and relaxed in a natural environment (park, forest or beach) than in an urban environment (Kaplan and Kaplan, 1989). Therefore, investing the idea of this theory in the architectural resilience of epidemics can help improve mental health, especially for those who spend more time indoors and when outside activities are limited (Morganti et al., 2022).	_ The landscapes and green spaces can provide a place to relax, improve air quality, improve physical health and reduce stress, which is important to minimize the spread of epidemics (Xie et al., 2020).
(c)	Proxemics Theory	Developed by the anthropologist Edward Twillich Hall in the 1960s, this theory is a branch of non-verbal communication that studies the use of space and distance in human interactions (Hall, 1973, p. 4). It is predicated on the notion that people have an innate need for personal space that is determined according to cultural and social determinants and personal preferences (Hall, 1973, p. 108). Proxemics is Used in many areas, including architecture, to create comfortable spaces and leads to controlled communication (Fezi, 2020).	_ Controlling the flow of people and ensuring that the safe distance of social distancing is maintained by employing features such as physical barriers, one-way traffic and automated doors (Pinheiro and Luís, 2020). _ The analysis of distance, spatial organization, users count, and surrounding area using predetermined measures (Cristani et al., 2020).
(d)	Healthy Building Approach	Healthy design and its apparent impact on architecture date back to the early 19th century due to collective urbanization and the emergence of construction challenges and health problems (Porter, 2005, p. 185). Then, became one of the directions of many specialists affected in this field of architecture (Campbell, 2005). This approach to design has gained widespread attention after the recent outbreak of pandemics to include many aspects of building design, emphasizing the role of architecture in the health and well-being of occupants (Capolongo, 2014).	_ Environmental quality, investment of natural systems, emphasis on prevention, safety and improvement of sensory environments. _ Functional resilience, accessibility, disease prevention, good functional organization, attention to the division of spaces, proximity, waste management,, the use of healthy building materials (Younis, 2021)

Integrating Systems

This paragraph focuses on the importance of integrating different adaptive systems to contribute to the provision of epidemic-resilience environments by highlighting a range of systems to extract the most prominent features that can be integrated with the architectural design of buildings, as shown in Table 4.

Table 4

A summary table of the features extracted from the most prominent adaptive systems (Source: Authors)

Theories And Approaches		Description	Features
(a)	Technological Systems	They are information systems designed to perform a specific function without relying on human design inputs. These systems can provide responsive and effective spaces for resisting epidemics (Mihalis, 2020).	_ Disinfection, early warning, monitoring, automation and indoor air quality improvement systems (Elabd et al., 2021; Pinheiro and Luís, 2020).
(b)	Environmental Systems	Environmental systems are a range of natural factors surrounding the building, such as sunlight, ventilation, natural lighting, and humidity. Integrating these systems has become necessary for creating living environments that are more effective in resisting epidemics (Hassan et al., 2020; Waheeb and Hemeida, 2022).	_ Improving indoor air quality by adopting passive design strategies for natural ventilation (Hassan et al., 2020; Waheeb and Hemeida, 2022). _ Improving the indoor environment quality by adopting passive design strategies for natural lighting (Azuma et al., 2020).
(c)	Sustainable Systems	Recently, after the outbreak of epidemics, a review of principles and standards assessing sustainability has made the issue of epidemic resilience a key sustainability priority (Tleuken et al., 2021; Tokazhanov et al., 2020).	_ Promoting health, well-being, energy and water efficiency, choosing safe materials, and prioritizing sustainable building design practices (Pinheiro and Luís, 2020).
(d)	Spatial Systems	Spatial systems refer to the basic framework for arranging building spaces and contribute to defining the hierarchy and circulation within areas (Peponis, 2010), so architects and designers use this concept to achieve the best user movement experience, and it is pivotal in determining the level of effectiveness of social distancing within a specific space (Abdul Nasir et al., 2021).	_ Improving social distancing effectiveness between users by providing spatial suitability for circulation and controlling movement behaviour within spaces (Mustafa and Ahmed, 2022).
(e)	Construction Systems	Construction systems refer to the methods, technologies and materials used in building construction and include all structural elements and components that provide stability to the building while achieving the desired function (Macdonald, 2001, p. xi).	_ Employing construction strategies such as modular construction, lightweight and adaptable structures and healthy building materials (Salman and Hameed, 2021b; Megahed and Ghoneim, 2020).

Results: Identification and Classification of Preventive Indicators

The recent experience of epidemics has been accompanied by the detection of many problems and weaknesses in the existing buildings' design that probably contribute to the increased risk of epidemics. For example, most indoor spaces contain surfaces and contaminable materials (Navaratnam et al., 2022). Poor ventilation and inadequately ventilated areas lead to the confinement and circulation of polluted air, increasing the risk of transmission. In addition to the problem of communal spaces and cramped spaces such as corridors and waiting areas, it is not easy to maintain social distancing (Mustafa and Ahmed, 2022). Thus, the design of existing buildings makes users more vulnerable to infection, as demonstrated by applying the lockdown and quarantine policy (Allam and Jones, 2020). Also, due to the outbreak of epidemics, many fundamental needs have emerged that relate to relieving stress and anxiety during the use of indoor spaces (Alnusairat et al., 2020). All these problems and other obstacles prompted the study to develop a theoretical framework for the essential preventive indicators proposed for use (if possible) to evaluate various types of existing buildings in terms of their resilience to epidemics to improve users' lives in terms of health.

Based on a review of previous literature and synthesis of information, a set of preventive indicators and Preventive solutions were identified, focusing mainly on addressing and evaluating the main weaknesses in the existing buildings' design that probably contribute to the increasing spread of epidemics and their association with the users' health and safety. These indicators have been classified into four main categories: the effectiveness of social distancing, indoor air quality, indoor environmental quality, and control and prevention engineering. These key indicators, in turn, are divided into a total of (9) sub-categories and (63) Preventive solutions classified based on the design variables related to those key indicators, as shown in Table 5.

Table 5

The main and sub-categories of protective indicators (PI.), (Source: Authors)

Main Categories of (PI.)	Sub-categories of (PI.)	Design Variables		Preventive Solutions
The Social Distancing Effectiveness (PI.1)	The universal design of outdoor spaces (PI.1.1)	Planning and organization		Reduce the distance of access
				Clarity of movement in external corridors
				Parking lots near the building
		Decentralization		Multiple outlets and external gates
				Functional Diversity and Zoning
				Increase open and purposeful spaces
		Healthy and sustainable mobility		Provision of pedestrian infrastructure
				Transportation accessibility
				Using smart mobility apps
	Movement control in indoor spaces (PI.1.2)	Safe distance elements	Interior spaces	Providing spatial intelligence techniques
				Providing doors that open without touching
				Providing sharing and communication tools
				Providing remote working technologies
				Installing physical barriers in narrow areas
				Use of movable furniture
				Separate entrances to crowded spaces
				Distinguishing between different functions
			Vertical movement elements	Provide touchless elevators
				Increased no. of vertical movement elem.
				Adequate space for social distancing
				Allocate one-way stairs for movement
				Clarity of location within floors
				Installation of indicative signs
	Spatial suitability for circulation (PI.1.3)	Permeability		Connectivity between spaces
		Wayfinding		An adequate field for visibility within spaces
		Privacy		Spatial depth between spaces
		Accessibility		Integration between spaces

Main Categories of (PI.)	Sub-categories of (PI.)	Design Variables		Preventive Solutions
Indoor Air Quality (PI.2)	Level of natural ventilation (PI.2.1)	Passive design strategies		Perfect orientation of the building
				Use cross ventilation
				Use stack ventilation
				Use of windbreaks
				inner courtyards
				The perfect design for exterior openings
	The efficiency of HVAC (PI.2.2)	Ventilation Type		Natural or hybrid ventilation
		Direction of airflow		One-way indirect flow
		Source distribution pattern		Linear or Networked Distribution
		Filtration techno-logies	Mechanical	High-Efficiency Filters (HEPA)
			Natural	Green Wall (Natural Plants)
				Micro-algae technique
		Disinfection techniques		Bipolar Ionization Technology (NBPI)
				UVGI (Type C) technology
				Non-Thermal Plasma Technology (airPHX)
Indoor Environmental Quality (PI.3)	Maximise natural lighting (PI.3.1)	Passive design strategies		Perfect orientation of the building
				The perfect design for courtyards
				Employing reflective interior surfaces
				Important spaces near exterior windows
				Employing reflective lighting systems
	Improve mental health (PI.3.2)	Design elements of therapeutic environments		Increasing natural outdoor spaces
				Provide windows with outdoor views
				Large and purposeful balcony design
				Use of elements, materials and natural colours
				Privacy and Personal Spaces
Control and Prevention Engineering (PI.4)	Proper selection of indoor materials (PI.4.1)	Internal and external surfaces		Use of smooth surfaces
				Use of interchangeable surfaces
				Use of healthy and sustainable materials
				Use of virus-resistant materials
				Use of cleanable materials
				Reduce the angles of the inner edges
	Self-cleaning spaces (PI.4.2)			Provision areas for sterilization devices
				Provision of sterilization and hand-washing equipment
				Installation of indicative marks for sanitizing common tools
				The multiplicity of bathrooms within the building's floors
				Provision of space for solid and contaminated waste

The Social Distancing Effectiveness (PI.1)

Social distancing is defined as a kinetic-spatial mechanism that keeps people at a safe distance from one another and prevents people from gathering in cramped and crowded spaces. Social distancing limits close contact between people to reduce the spread of epidemics (Cristani et al., 2020). This main category includes three other sub-indicators and (27) Preventive solutions related to addressing the spatial and motor aspects that can contribute to promoting and evaluating the effectiveness of social distancing, as listed in Table 5.

_ The Universal Design of Outdoor Spaces (PI.1.1): Designers can create outdoor spaces that promote social distancing and encourage safe user interaction by relying on universal design principles or elements (Mela and Varelidis, 2022). Reducing access distance and traffic clarity affects how users interact and help maintain social distancing (Hariyani and Pratama, 2021). Kinetic and spatial decentralization reduces the density of people in one area allowing for more effective social distancing by creating multiple entry and exit points or zoning and functional diversity, people can spread more efficiently and maintain a safe distance (Abdul Nasir et al., 2021). Sustainable mobility can also contribute to compliance with social distancing guidelines by encouraging the use of intelligent mobility applications and providing infrastructure for alternative transport, such as cycling or walking, helping to reduce people's density in one area (Megahed and Abdel-Kader, 2022).

_ Movement Control in Indoor Spaces (PI.1.2): The effectiveness of social distancing in indoor spaces is determined by the type of activities practised, the duration of the interaction of those activities and the number of users (Ugail et al., 2021). This indicator includes preventive solutions to enhance safe distance, which is the use of physical elements, such as barriers that can be installed in narrow areas (Lewis et al., 2020), and other technological elements, such as spatial intelligence techniques, sharing tools and communication during space mobility (CB Insights Research, 2020). In addition to factors contributing to the promotion of physical separation, such as the use of movable furniture and the installation of indicative markings (Güzelci et al., 2020).

_ Spatial Suitability for Circulation (PI.1.3): Regarding planning, the effectiveness of social distancing compliance is Affected by the properties of the spatial composition, which controls the method and type of interaction between users, which in turn is influential in determining the extent to which social distancing can be maintained (Mustafa and Ahmed, 2022; M. Hameed Al-Delfi and S. Salman, 2022; Ugail et al., 2021). For instance, a place with well-defined paths and sections designated for various activities can ease congestion and promote physical distance (Abdul Nasir et al., 2021).

Indoor Air Quality (PI.2)

The key elements that can reduce the dangers of epidemics spreading through indoor air are covered by this indicator. There is a direct link between COVID-19 infection and indoor air quality, particularly in congested and inadequately ventilated areas. So, this critical indicator is crucial in creating and evaluating indoor spaces in terms of epidemic resilience that spreads quickly through indoor air Hassan et al., 2020; Megahed and Ghoneim, 2021). Internal air quality can be improved by controlling and improving the quality of ventilation sources (Sloan Brittain et al., 2021). This main category includes two sub-indicators and (15) Preventive solutions, as listed in Table 5.

_ Level of Natural Ventilation (PI.2.1): Natural ventilation is crucial for limiting epidemics' spread and their causes' transmission (Qian et al., 2010). Outdoor air enters spaces to mitigate the high number of viruses generated by users' movement and activities. Appropriate ventilation also reduces pollution of space's internal surfaces by removing viral particles before falling and depositing them on surfaces (EPA, 2021; Qian et al., 2010). Adopting passive design strategies is one of the effective preventive solutions for improving indoor air quality (Cynthia Permata Dewi, 2020; Waheeb and Hemeida, 2022).

- The Efficiency of HVAC (PI.2.2): A proven relationship exists between ventilation systems and the spread of epidemics (Chen et al., 2022). Researchers recently studied the probability of high infection rates in enclosed spaces. They recommended the treatment of recycled air through the operationalization of improved operational practices and the installation of high-efficiency filters (HEPA) & (MERV) and maintaining it properly (Megahed and Ghoneim, 2021). Moreover, indoor air quality can be improved by integrating natural-loving design ideas into the interior space design of buildings (Asim et al., 2021).

Indoor Environmental Quality (PI.3)

Essentially, (IEQ) refers to the quality of the living environment within buildings (Lai et al., 2009). It is based on a range of internal variables such as the environment such as natural lighting, and other variables related to improving the mental health of occupants as elements of the design of therapeutic environments that will raise users' well-being and avoid the building syndrome (SBS) (Al horr et al., 2016; Chen et al., 2022). This main category includes two sub-indicators and (10) Preventive solutions related to maximizing natural lighting and improving mental health that can enhance the level of (IEQ) and evaluate epidemic resilience, as listed in Table 5.

- Maximise Natural Lighting (PI.3.1): In preventive terms, natural lighting is another essential factor in reducing the spread of epidemics (Peters and Halleran, 2020). In one of the studies concerned with the viral clusters carried in the indoor air, daylight appeared to harm these viral clusters and their attachment to the human body in spaces with a percentage of daylight compared to dark areas (Azuma et al., 2020). To obtain appropriate levels of natural lighting in the interior spaces through one of the preventive solutions, which is the adoption of passive design strategies with the employment of treatments that maximize natural lighting to improve epidemic resilience in the interior spaces (Waheeb and Hemeida, 2022).
- Improve Mental Health (PI.3.2): Recent outbreaks have forced people to stay home significantly more than usual due to stringent preventive measures implemented during the pandemic (Panneer et al., 2022). This type of person's life can negatively affect their mental health, especially Individuals used to space with a poor level of (IEQ) (Morganti et al., 2022). Therefore, it is crucial to maintain a healthy psychological state. That improvement can be made by putting various strategies into practice or by utilizing aspects of the therapeutic environment design (Morganti et al., 2022; Peters and Halleran, 2020).

Control and Prevention Engineering (PI.4)

It has become essential to think about all aspects of building design that can be the host of epidemiological causes. So, this key indicator highlights addressing the risks of epidemic spread by engineering control and prevention in terms of adequately selecting indoor materials and achieving self-cleaning of spaces. This main category includes two sub-indicators and (11) Preventive solutions, as listed in Table 5.

- Proper Selection of Indoor Materials (PI.4.1): The selection of materials and finish quality in building design are critical to creating healthy environments. The spread of viruses is affected by the mediator that settles on it and the type of material in addition to the cleaning properties, as this controls the activity and age of viruses (Dietz et al., 2020; Van et al., 2020). It has been confirmed that there are materials that can reduce the age of viruses called antimicrobial materials (Navaratnam et al., 2022; Tleuken et al., 2021).

- Self-Cleaning Spaces (PI.4.2): Some preventive measures that can be used to keep users safe are needed for infection prevention, such as controlling contaminated solid waste and continuous disinfection of spaces, particularly in public areas (Van Doremalen et al., 2020) in addition to providing sterilization equipment and regions dedicated to them (Pinheiro and Luís, 2020).

Discussion

Buildings Design as An Epidemic-Resilient Architecture

Epidemic-resilient architecture revolves around building design capable of providing a healthy, safe and resilient environment. According to the complexity of the matter, it is no longer safe to rely on individual strategies but instead on a multi-layered approach to protection. This architecture improves available strategies, methods and tools that are more resilient and effective in responding appropriately to epidemics (Andrei Fezi, 2021; Megahed and Ghoneim, 2020). Therefore, choosing solutions to improve design depends on more than one influential factor that poses another challenge to using or planning them as long-term repairs, and these factors are:

- Spatial factors in the design and planning of the building spaces contribute to reducing the spread of epidemics by controlling the level of social distancing effectiveness among users.
- Environmental factors, such as the level of air quality and natural lighting, affect resilience to epidemics by controlling the size and shape of indoor airborne viral interactions.
- Physical factors as materials and internal surfaces, affect epidemic resilience by addressing the control of indirect transmission dynamics.
- Technical factors are instrumental in reducing the spread of epidemics by controlling direct and indirect transmission dynamics.

Building design must prioritize enhancing the effectiveness of social distance, especially in overcrowded buildings, to create resilient architectural systems in response to epidemics (Abdul Nasir et al., 2021). That improvement can be made by implementing design and spatial planning strategies that focus on motor control in spaces, reducing random movement and motor intersection among users (Mustafa and Ahmed, 2022).

Building design should focus on natural ventilation and avoid depending only on artificial environmental conditions and mechanical ventilation. To create more protective spaces, indoor air quality must be improved by redesigning air pollutants around buildings using building morphology and a passive urban approach based on a detailed analysis of local climate and location factors (Megahed and Ghoneim, 2021); Additionally, the passive design principles of natural ventilation and indoor air distribution can be activated. Buildings with high pollution levels can depend on disinfection processes and practical techniques to improve air quality.

The right level of (IEQ), that improvement can be accomplished by utilizing the most influential environmental design techniques to maximize natural illumination and utilizing components of natural systems that will improve inhabitants' well-being and health (Waheeb and Hemeida, 2022). To address epidemic risk and meet the most important self-cleaning requirements for spaces, the building design for epidemic resistance must also incorporate the proper selection and quality of materials.

Potential Problems and Proposed Solutions

When using the preventive indicators suggested by the research to evaluate the design of existing buildings, some potential problems may arise that cause a reduction in resilience (Tleuken et al., 2021; Tokazhanov et al., 2020). Therefore, the research proposes a range of solutions that can be commensurate with the magnitude of the potential problem and ease of implementation by depending on specific engineering controls and modifications that can be implemented on existing structures, as shown in Table 6.

Table 6

Highlights the main potential problems and solutions proposed according to preventive indicators (Source: Authors)

Main Categories of (PI.)	Sub-categories of (PI.)	Potential Problems	Proposed Solutions
(PI.1)	(PI.1.1) & (PI.1.2)	Poor physical segregation	Increase the physical separation between users by placing physical barriers, programming entry and exit and scheduling the use of spaces, separating different functions and changing some functional programs at the horizontal and vertical levels.
	(PI.1.2)	Limited provision of safe distance implementation requirements	Using guiding signs, increasing the distance between seating, allocating one-way stairs, reducing occupancy density according to space capacity, and reducing the use of narrow public spaces.
	(PI.1.3)	Low level of spatial suitability for circulation	The most effective routing strategies can be adopted in determining the paths of movement and increased accessibility of spaces by increasing the number of entrances and directing internal movement towards the intended areas.
			Focusing on using flexible patterns of furniture arrangement. as well as focusing on the priorities of the functional distribution of spaces and increasing the use of internal guidance strategies.
		Clear limitations of the ability to expand indoor spaces	The research suggests depending on the reuse of unused spaces instead of conducting architectural interventions that adopt changes or transformation processes to cover the shortage in the area when implementing social distancing measures between users.
(PI.2)	(PI.2.1)	Poor orientation of the building	Focusing on other solutions to improve indoor air quality, such as disinfection and filtration techniques. Concerning courtyards, this can be offset by increasing natural ventilation rates within spaces through the programmed opening of external windows and doors at the end of the main corridors.
	(PI.2.2)	Limited use of purification techniques	Given the difficulty of providing them, the research suggests compensating for their usefulness by adopting other design treatments, such as increasing natural ventilation rates and improving ventilation and air conditioning system design.
		Not using design standards	Reducing the occupational intensity of spaces or using outdoor spaces for specific activities, focusing on increasing natural ventilation rates at the required level by opening outdoor windows.
(PI.3)	(PI.3.1)	Limited use of internal treatments	Also, because it is impossible to change the current orientation of the building, the research suggests relying on other solutions to improve the permeability of the glazing material, using transparent curtains or allocating open outdoor spaces for some activities.
	(PI.3.2)	Non-employment of therapeutic environments design elements.	The research suggests using natural elements within spaces, using natural materials and colours, and reusing balconies overlooking landscapes.
(PI.4)	(PI.4.1)	Improper selection of materials and finishes	Due to the difficulty of changing exterior materials and finishes, the research suggests relying on internal surface treatment as more effective in reducing the spread of epidemics through virus-resistant materials and continuous cleaning and sterilization of common inner surfaces and materials.

Epidemic-Resilient Design: Assistance Tools for Evaluation and Improvement

The risk of recent outbreaks has enhanced the possibility of specialists using modelling tools and techniques and investing them in analysis, simulation and monitoring to study transmission factors in existing buildings' internal or external spaces (Megahed and Ghoneim, 2021). Each tool studies a particular design aspect while providing a complete understanding of the aspects and indicators to be reviewed. For example, to research and evaluate indoor spaces from a social distancing perspective, a space syntax methodology can be used using (Deapthmap) software tools (M. Hameed Al-Delfi and S. Salman, 2022; Mustafa and Ahmed, 2022).

As for the evaluation and examination of the indoor air quality Indicator, computer-assisted design (CAD), building information modelling (BIM) and computational fluid dynamics (CFD) tools can be used. Can also collaborate with mechanical engineers in the analysis and simulation of airflow in the interior and surrounding spaces of buildings to study the design factors and evaluate their performance and then provide some improvements that will maximize and improve natural ventilation (Hassan and Megahed, 2021; Waheeb and Hemeida, 2022). It is, therefore, possible to invest these tools in collaboration with other engineering disciplines to evaluate specific existing building models and provide complete information on potential design problems and weaknesses to diagnose appropriate solutions that contribute to improving the determinability of resilient epidemics (Güzelci et al., 2020; Hassan et al., 2020).

Conclusions

This study explored a group of the most prominent preventive indicators that the research recommends to be applied by specialists. Therefore, this study contributed to how to make existing buildings living environments capable of overcoming the challenges of epidemics by employing the recommended effective design strategies and preventive solutions to prevent epidemics. Moreover, this study investigated theoretical and practical knowledge and current information in the architectural and urban literature, public health and environmental sciences.

Based on the research's main findings, this study contributed innovatively to its field of study by identifying essential preventive indicators within a theoretical framework consisting of four main indicators, nine other sub-indicators, and more than (60) preventive solutions. Furthermore, the study suggests using the following indicators that are most effective in evaluating the design of existing buildings in terms of their response to epidemics:

- Effectiveness of social distancing: as a primary indicator in assessing the extent to which premises can facilitate compliance with social distancing by evaluating the design's spatial and kinetic aspects to reduce contact and physical convergence between occupants.
- Indoor air quality: the second preventive indicator concerned with monitoring the level of internal air quality and mitigating viral accumulations suspended in the air through activate the role of natural ventilation sources by employing passive design strategies and monitoring ventilation and air conditioning systems through (HVAC) design.
- Indoor environmental quality: This preventive indicator evaluates the risk of epidemics resulting from poor internal environmental quality. The results of the evaluation of this indicator depend on the extent to which the building's design achieves aspects related to the health and well-being of the occupants, such as maximizing natural lighting and employing elements of communication with natural systems.
- Control and prevention engineering: The last indicator relates to evaluating existing buildings regarding the quality of materials and their characteristics contributing to reducing the spread of epidemics.

The research recommends that all specialists in the field of construction and design, including engineers, need to obtain a training model in the field of public health. Moreover, it is recommended to use these protective indicators that have been proposed to evaluate existing buildings concerning epidemic resilience. However, depending on the function of the building (educational, residential or commercial), the nature of the occupants, the scale of the design problems and the nature of the proposed solutions (reactive or proactive solutions). All of these hotspots could be valuable opportunities for further research in the future.

References

Abdul Nasir, N. A. B., Hassan, A. S., Khozaei, F., & Abdul Nasir, M. H. Bin. (2021). Investigation of spatial configuration management on social distancing of recreational clubhouse for COVID-19 in Penang, Malaysia. International Journal of Building Pathology and Adaptation, 39(5), 782-810. https://doi.org/10.1108/IJBPA-08-2020-0072

Al horr, Y., Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A., & Elsarrag, E. (2016). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. International Journal of Sustainable Built Environment, 5(1), 1-11. https://doi.org/10.1016/j.ijsbe.2016.03.006

Alhusban, A. A., Alhusban, S. A., & Alhusban, M. A. (2022). How the COVID-19 pandemic would change the future of architectural design. Journal of Engineering, Design and Technology, 20(1), 339-357. https://doi.org/10.1108/JEDT-03-2021-0148

Alkhalaf, M., Ilinca, A., & Hayyani, M. Y. (2023). CFD investigation of ventilation strategies to remove contaminants from a hospital room. Designs, 7(1), 5. https://doi.org/10.3390/designs7010005

Allam, Z., & Jones, D. S. (2020). Pandemic stricken cities on lockdown. where are our planning and design professionals [now, then and into the future]? Land Use Policy, 97, 104805. https://doi.org/10.1016/j.landusepol.2020.104805

Alnusairat, S., Al Maani, D., & Al-Jokhadar, A. (2020). Architecture students' satisfaction with and perceptions of online design studios during COVID-19 lockdown: the case of Jordan universities. Archnet-IJAR: International Journal of Architectural Research, 15(1), 219-236. https://doi.org/10.1108/ARCH-09-2020-0195

Andrei Fezi, B. (2021). The role of architecture and urbanism in preventing pandemics. in SARS-CoV-2 origin and COVID-19 pandemic across the globe (pp. 1-20). Rijeka: IntechOpen. https://doi.org/10.5772/intechopen.98294

Asim, F., Chani, P. S., & Shree, V. (2021). Impact of COVID-19 containment zone built-environments on students' mental health and their coping mechanisms. Building and Environment, 203, 108107. https://doi.org/10.1016/j.buildenv.2021.108107

Azuma, K., Yanagi, U., Kagi, N., Kim, H., Ogata, M., & Hayashi, M. (2020). Environmental factors involved in SARS-CoV-2 transmission: effect and role of indoor environmental quality in the strategy for COVID-19 infection control. Environmental Health and Preventive Medicine, 25(1), 66. https://doi.org/10.1186/s12199-020-00904-2

Bell, S., & Morse, S. (2012). Sustainability Indicators. Routledge. https://doi.org/10.4324/9781849772723

Browning, W., Ryan, C., & Clancy, J. (2014). 14 Patterns of Biophilic Design ImprovIng HealtH & Well-BeIng In tHe BuIlt envIronment. In Terrapin Bright Green,LLC (Sally Augu). New York.

Campbell, M. (2005). What tuberculosis did for modernism: the influence of a curative environment on modernist design and architecture. Medical History, 49(4), 463-488. https://doi.org/10.1017/S0025727300009169

Capolongo, S. (2014). Architecture as a generator of health and well-being. Journal of Public Health Research, 3(1), jphr.2014.276. https://doi.org/10.4081/jphr.2014.276

CB Insights Research. (2020, 23 July). Reopening: the tech-enabled office in a post-covid world. CBINSIGHTS. https://www.cbinsights.com/research/report/reopening-office-tech-work-post-covid/#elevators

CDC. (2021, 24 May). Basics of COVID-19. Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/your-health/about-covid-19/basics-covid-19.html

Chen, Y., Lei, J., Li, J., Zhang, Z., Yu, Z., & Du, C. (2022). Design characteristics on the indoor and outdoor air environments of the COVID-19 emergency hospital. Journal of Building Engineering, 45(September 2021), 103246. https://doi.org/10.1016/j.jobe.2021.103246

Chick, R. C., Clifton, G. T., Peace, K. M., Propper, B. W., Hale, D. F., Alseidi, A. A., & Vreeland, T. J. (2020). Using technology to maintain the education of residents during the COVID-19 pandemic. Journal of Surgical Education, 77(4), 729-732. https://doi.org/10.1016/j.jsurg.2020.03.018

Cristani, M., Bue, A. Del, Murino, V., Setti, F., & Vinciarelli, A. (2020). The visual social distancing problem. IEEE Access, 8, 126876-126886. https://doi.org/10.1109/ACCESS.2020.3008370

Cynthia Permata Dewi. (2020). Optimization of natural ventilation in building as passive design strategy for health security. PROCEEDING INTERNATIONAL CONFERENCE ON ENGINEERING, 1(1), 25-31. https://doi.org/10.36728/icone.v1i1.1267

Damani, N. (2019). Manual of Infection Prevention and Control. Oxford University Press, USA. https://doi.org/10.1093/med/9780198815938.001.0001

Dear, M., & Flusty, S. (1998). Postmodern urbanism. Annals of the Association of American Geographers, 88(1), 50-72. https://doi.org/10.1111/1467-8306.00084

Dietz, L., Horve, P. F., Coil, D. A., Fretz, M., Eisen, J. A., & Van Den Wymelenberg, K. (2020). 2019 Novel coronavirus (COVID-19) pandemic: built environment considerations to reduce transmission. MSystems, 5(2). https://doi.org/10.1128/mSystems.00245-20

Elabd, N. M., Mansour, Y. M., & Khodier, L. M. (2021). Utilizing innovative technologies to achieve resilience in heritage buildings preservation. Developments in the Built Environment, 8, 100058. https://doi.org/10.1016/j.dibe.2021.100058

Emmanuel, U., Osondu, E. D., & Kalu, K. C. (2020). Architectural design strategies for infection prevention and control (IPC) in health-care facilities: towards curbing the spread of Covid-19. In Journal of Environmental Health Science and Engineering (Vol. 18, Issue 2, pp. 1699-1707). https://doi.org/10.1007/s40201-020-00580-y

EPA. (2021). Ventilation and Coronavirus (COVID-19). United States Environmental Protection Agency. https://www.epa.gov/coronavirus/ventilation-and-coronavirus-covid-19

Fezi, B. A. (2020). Health engaged architecture in the context of COVID-19. Journal of Green Building, 15(2), 185-212. https://doi.org/10.3992/1943-4618.15.2.185

Grigoriadou, E.T. (2020). The urban balcony as the new public space for well-being in times of social distancing. Cities Heal. 00, 1-4. https://doi.org/10.1080/23748834.2020.1795405

Gür, M. (2022). Post-pandemic lifestyle changes and their interaction with resident behavior in housing and neighborhoods: Bursa, Turkey. Journal of Housing and the Built Environment, 37(2), 823-862. https://doi.org/10.1007/s10901-021-09897-y

Güzelci, O. Z., Şen Bayram, A. K., Alaçam, S., Güzelci, H., Akkuyu, E. I., & Şencan, İ. (2020). Design tactics for enhancing the adaptability of primary and middle schools to the new needs of postpandemic reuse. Archnet-IJAR: International Journal of Architectural Research, 15(1), 148-166. https://doi.org/10.1108/ARCH-10-2020-0237

Hall, E. T. (1973). The Hidden Dimension. Leonardo, 6(1), 94. https://doi.org/10.2307/1572461

Hariyani, D. S., & Pratama, A. R. (2021). A pandemic response to the issues of inclusivity and accessibility in green open spaces. In IOP Conference Series: Earth and Environmental Science (Vol. 780, Issue 1). https://doi.org/10.1088/1755-1315/780/1/012033

Hassan, Asmaa M., & Megahed, N. A. (2021). COVID-19 and urban spaces: a new integrated CFD approach for public health opportunities. Building and Environment, 204, 108131. https://doi.org/10.1016/j.buildenv.2021.108131

Hassan, Asmaa Mohammed, Fatah El Mokadem, A. A., Megahed, N. A., & Abo Eleinen, O. M. (2020). Improving outdoor air quality based on building morphology: numerical investigation. Frontiers of Architectural Research, 9(2), 319-334. https://doi.org/10.1016/j.foar.2020.01.001

Hu, Q., He, L., & Zhang, Y. (2021). Community transmission via indirect media-to-person route: a missing link in the rapid spread of COVID-19. Frontiers in Public Health, 9. https://doi.org/10.3389/fpubh.2021.687937

Kaplan, R., & Kaplan, S. (1989). The experience of nature: a psychological perspective. Cambridge: Cambridge University Press.

Kapoor, N. R., Kumar, A., Meena, C. S., Kumar, A., Alam, T., Balam, N. B., & Ghosh, A. (2021). A systematic review on indoor environmental quality in naturally ventilated school classrooms: a way forward. Advances in Civil Engineering, 2021, 1-19. https://doi.org/10.1155/2021/8851685

Lewis, P., Nordensn, G., Lewis, D. j., & Tsurumaki, M. (2020). Manual of physical distancing space, time, and cities in the era of Covid-19. In Princeton University. New York.

M. Hameed Al-Delfi, A., & S. Salman, A. (2022). Investigating the impact of educational space design in fostering social distancing: a case study of the University of Technology buildings, Iraq. Journal of Sustainable Architecture and Civil Engineering, 31(2), 39-57. https://doi.org/10.5755/j01.sace.31.2.30746

Macdonald, A. J. (2001). Structure and Architecture (Second edi). Architectural Press.

Majewska, A., Denis, M., Jarecka-Bidzińska, E., Jaroszewicz, J., Krupowicz, W. (2022). Pandemic resilient cities: Possibilities of repairing Polish towns and cities during COVID-19 pandemic. Land use policy 113, 105904. https://doi.org/10.1016/j.landusepol.2021.105904

Maturana, B., Salama, A.M., McInneny, A., 2021. Architecture, urbanism and health in a post-pandemic virtual world. Archnet-IJAR Int. J. Archit. Res. 15, 1-9. https://doi.org/10.1108/ARCH-02-2021-0024

Matz, C. J., Stieb, D. M., & Brion, O. (2015). Urban-rural differences in daily time-activity patterns, occupational activity and housing characteristics. Environmental Health, 14(1), 88. https://doi.org/10.1186/s12940-015-0075-y

Megahed, N. A., & Abdel-Kader, R. F. (2022). Smart cities after COVID-19: building a conceptual framework through a multidisciplinary perspective. Scientific African, 17, e01374. https://doi.org/10.1016/j.sciaf.2022.e01374

Megahed, N. A., & Ghoneim, E. M. (2020). Antivirus-built environment: lessons learned from Covid-19 pandemic. Sustainable Cities and Society, 61, 102350. https://doi.org/10.1016/j.scs.2020.102350

Megahed, N. A., & Ghoneim, E. M. (2021). Indoor air quality: rethinking rules of building design strategies in post-pandemic architecture. Environmental Research, 193, 110471. https://doi.org/10.1016/j.envres.2020.110471

Mela, A., & Varelidis, G. (2022). Effects of the COVID-19 pandemic on the use and attitudes towards urban public spaces. Journal of Sustainable Architecture and Civil Engineering, 31(2), 85-95. https://doi.org/10.5755/j01.sace.31.2.31545 https://doi.org/10.5755/j01.sace.31.2.31545

Mihalis, K. (2020). Ten technologies to fight coronavirus. European Parliamentary Research Service, April, 1-20.

Morganti, A., Brambilla, A., Aguglia, A., Amerio, A., Miletto, N., Parodi, N., Porcelli, C., Odone, A., Costanza, A., Signorelli, C., Serafini, G., Amore, M., & Capolongo, S. (2022). Effect of housing quality on the mental health of university students during the COVID-19 lockdown. International Journal of Environmental Research and Public Health, 19(5), 2918. https://doi.org/10.3390/ijerph19052918

Mustafa, F. A., & Ahmed, S. S. (2022). The role of waiting area typology in limiting the spread of COVID-19: outpatient clinics of Erbil hospitals as a case study. Indoor and Built Environment, 0(0), 1420326X2210796. https://doi.org/10.1177/1420326X221079616

Navaratnam, S., Nguyen, K., Selvaranjan, K., Zhang, G., Mendis, P., & Aye, L. (2022). Designing post COVID-19 buildings: approaches for achieving healthy buildings. Buildings, 12(1), 74. https://doi.org/10.3390/buildings12010074

Panneer, S., Kantamaneni, K., Akkayasamy, V. S., Susairaj, A. X., Panda, P. K., Acharya, S. S., Rice, L., Liyanage, C., & Pushparaj, R. R. B. (2022). The great lockdown in the wake of covid-19 and its implications: lessons for low and middle-income countries. International Journal of Environmental Research and Public Health, 19(1), 610. https://doi.org/10.3390/ijerph19010610

Peponis, J. (2010). Geometries of architectural design: shape and spatial configuration. Journal of Space Syntax, 1(1), 133-148.

Peters, T., & Halleran, A. (2020). How our homes impact our health: using a COVID-19 informed approach to examine urban apartment housing. Archnet-IJAR: International Journal of Architectural Research, 15(1), 10-27. https://doi.org/10.1108/ARCH-08-2020-0159

Pinheiro, M. D., & Luís, N. C. (2020). COVID-19 could leverage a sustainable built environment. Sustainability, 12(14), 5863. https://doi.org/10.3390/su12145863

Porter, D. (2005). Health, Civilisation and the State. Routledge. https://doi.org/10.4324/9780203980576

Priyanka, Choudhary, O. P., Singh, I., & Patra, G. (2020). Aerosol transmission of SARS-CoV-2: The unresolved paradox. Travel Medicine and Infectious Disease, 37, 101869. https://doi.org/10.1016/j.tmaid.2020.101869

Qian, H., Li, Y., Seto, W. H., Ching, P., Ching, W. H., & Sun, H. Q. (2010). Natural ventilation for reducing airborne infection in hospitals. Building and Environment, 45(3), 559-565. https://doi.org/10.1016/j.buildenv.2009.07.011

Salama, A. M. (2020). Coronavirus questions that will not go away: interrogating urban and socio-spatial implications of COVID-19 measures. Emerald Open Research, 2, 14. https://doi.org/10.35241/emeraldopenres.13561.1

Salman, A. S., & Hameed, T. M. (2021b). Flexibility in sustainable architecture output Resistance to epidemics. IOP Conference Series: Earth and Environmental Science, 779(1), 012034. https://doi.org/10.1088/1755-1315/779/1/012034

Salman, A.S., Hameed, T.M. (2021a). Anti-Epidemic architecture strategies "COVID-19an entrance to the design of a preventive architectural product ". J. Eng. Sci. Technol. 16, 4109-4120.

Sharma, A., & Borah, S. B. (2022). Covid-19 and domestic violence: an indirect path to social and economic crisis. Journal of Family Violence, 37(5), 759-765. https://doi.org/10.1007/s10896-020-00188-8

Sloan Brittain, O., Wood, H., & Kumar, P. (2021). Prioritizing indoor air quality in building design can mitigate future airborne viral outbreaks. Cities & Health, 5(sup1), S162-S165. https://doi.org/10.1080/23748834.2020.1786652

Tleuken, A., Tokazhanov, G., Guney, M., Turkyilmaz, A., & Karaca, F. (2021). Readiness assessment of green building certification systems for residential buildings during pandemics. In Sustainability (Switzerland) (Vol. 13, Issue 2, pp. 1-31). https://doi.org/10.3390/su13020460

Tokazhanov, G., Tleuken, A., Guney, M., Turkyilmaz, A., & Karaca, F. (2020). How is COVID-19 experience transforming sustainability requirements of residential buildings? a review. Sustainability, 12(20), 8732. https://doi.org/10.3390/su12208732

Ugail, H., Aggarwal, R., Iglesias, A., Howard, N., Campuzano, A., Suárez, P., Maqsood, M., Aadil, F., Mehmood, I., Gleghorn, S., Taif, K., Kadry, S., & Muhammad, K. (2021). Social distancing enhanced automated optimal design of physical spaces in the wake of the COVID-19 pandemic. Sustainable Cities and Society, 68, 102791. https://doi.org/10.1016/j.scs.2021.102791

Van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J. L., Thornburg, N. J., Gerber, S. I., Lloyd-Smith, J. O., de Wit, E., & Munster, V. J. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. New England Journal of Medicine, 382(16), 1564-1567. https://doi.org/10.1056/NEJMc2004973

Waheeb, M. I., & Hemeida, F. A. (2022). Study of natural ventilation and daylight in a multi-storey residential building to address the problems of COVID-19. Energy Reports, 8(May), 863-880. https://doi.org/10.1016/j.egyr.2022.07.078

WHO. (2020, April,13). WHO Director-General's opening remarks at the media briefing on COVID. https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020

Xie, J., Luo, S., Furuya, K., & Sun, D. (2020). Urban parks as green buffers during the COVID-19 pandemic. Sustainability, 12(17), 6751. https://doi.org/10.3390/su12176751

Yaseen, F. R., & Mustafa, F. A. (2023). Visibility of nature-connectedness in school buildings: An analytical study using biophilic parameters, space syntax, and space/nature syntax. Ain Shams Engineering Journal, 14(5), 101973. https://doi.org/10.1016/j.asej.2022.101973

Younis, G. M. (2021). Design strategies for healing internal environments and workplaces. a theoretical framework. Journal of Sustainable Architecture and Civil Engineering, 29(2), 33-48. https://doi.org/10.5755/j01.sace.29.2.28497

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