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

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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.

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).
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.

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...
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

<table>
<thead>
<tr>
<th>Current Aspects</th>
<th>Literature</th>
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<tbody>
<tr>
<td><strong>Epidemic Resilient Architecture Strategies</strong></td>
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<tr>
<td>Physical strategies</td>
<td>(Grigoriadou, 2020), (Majewska et al., 2022), (Maturana et al., 2021), (Megahed and Abuel-Kader, 2022), (Megahed and Ghoneim, 2020), (Mouratidis, 2022), (Peters and Halleran, 2020), (Pinheiro and Luís, 2020).</td>
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<tr>
<td>Architectural strategies</td>
<td>(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).</td>
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<tr>
<td>Technology Strategies</td>
<td>(Chick et al., 2020), (Elabed et al., 2021), (Mihalis, 2020).</td>
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<tr>
<td><strong>Epidemic Resilient Architecture Features</strong></td>
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<tr>
<td>Resilience</td>
<td>Transformation (Chick et al., 2020), (Megahed and Ghoneim, 2020).</td>
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<tr>
<td>Mobility</td>
<td>(Azuma et al., 2020), (Megahed and Ghoneim, 2020).</td>
</tr>
<tr>
<td>Adaptation</td>
<td>(Alhusban et al., 2022), (Güzelci et al., 2020).</td>
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<tr>
<td>Responsive</td>
<td>(Alhusban et al., 2022), (Hariyani and Pratama, 2021).</td>
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<tr>
<td><strong>Epidemic Resilient Architecture Standards</strong></td>
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<td>Ventilation system standards</td>
<td>(Alkhalaf et al., 2023), (Asim et al., 2021), (Chen et al., 2022), (Hassan et al., 2020), (Megahed and Ghoneim, 2021).</td>
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<tr>
<td>Space Requirements</td>
<td>(Al horr et al., 2016), (Asim et al., 2021), (Chen et al., 2022), (Morganti et al., 2022), (Younis, 2021).</td>
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</table>
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 (Alhorr 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.

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).

**Material and Methods**

![Fig. 2](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 (Pl.1.1)).

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, includ-
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 theories, approaches, and adaptive systems to promote healthier, safer, and more sustainable environments.

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; 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).

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>
<thead>
<tr>
<th>Theories And Approaches</th>
<th>Description</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Biophilic Design Theory</td>
<td>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).</td>
<td>- Ventilation and natural lighting (Waheeb and Hemeida, 2022).</td>
</tr>
<tr>
<td>(b) Attention Recovery Theory (ART)</td>
<td>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).</td>
<td>- 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).</td>
</tr>
<tr>
<td>(c) Proxemics Theory</td>
<td>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).</td>
<td>- 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).</td>
</tr>
<tr>
<td>(d) Healthy Building Approach</td>
<td>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).</td>
<td>- Environmental quality, investment of natural systems, emphasis on prevention, safety and improvement of sensory environments.</td>
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</table>
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>
<thead>
<tr>
<th>Theories And Approaches</th>
<th>Description</th>
<th>Features</th>
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<tbody>
<tr>
<td>(a) Technological Systems</td>
<td>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).</td>
<td>- Disinfection, early warning, monitoring, automation and indoor air quality improvement systems (Elabd et al., 2021; Pinheiro and Luis, 2020).</td>
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<tr>
<td>(b) Environmental Systems</td>
<td>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).</td>
<td>- 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 (Azuama et al., 2020).</td>
</tr>
<tr>
<td>(c) Sustainable Systems</td>
<td>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).</td>
<td>- Promoting health, well-being, energy and water efficiency, choosing safe materials, and prioritizing sustainable building design practices (Pinheiro and Luis, 2020).</td>
</tr>
<tr>
<td>(d) Spatial Systems</td>
<td>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).</td>
<td>- Improving social distancing effectiveness between users by providing spatial suitability for circulation and controlling movement behaviour within spaces (Mustafa and Ahmed, 2022).</td>
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<tr>
<td>(e) Construction Systems</td>
<td>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).</td>
<td>- Employing construction strategies such as modular construction, lightweight and adaptable structures and healthy building materials (Salman and Hameed, 2021b; Megahed and Ghoneim, 2020).</td>
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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>
<thead>
<tr>
<th>Main Categories of (PI.)</th>
<th>Sub-categories of (PI.)</th>
<th>Design Variables</th>
<th>Preventive Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Social Distancing Effectiveness (PI.1)</td>
<td>The universal design of outdoor spaces (PI.1.1)</td>
<td>Planning and organization</td>
<td>Reduce the distance of access</td>
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<td>Clarity of movement in external corridors</td>
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<td>Parking lots near the building</td>
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<td></td>
<td>Decentralization</td>
<td>Multiple outlets and external gates</td>
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<td></td>
<td>Functional Diversity and Zoning</td>
<td>Increase open and purposeful spaces</td>
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<td>Healthy and sustainable mobility</td>
<td>Provision of pedestrian infrastructure</td>
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<td></td>
<td>Transportation accessibility</td>
<td>Using smart mobility apps</td>
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<td>Movement control in indoor spaces (PI.1.2)</td>
<td>Interior spaces</td>
<td>Providing spatial intelligence techniques</td>
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<td>Providing doors that open without touching</td>
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<td>Providing sharing and communication tools</td>
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<td>Providing remote working technologies</td>
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<td>Installing physical barriers in narrow areas</td>
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<td>Use of movable furniture</td>
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<td>Separate entrances to crowded spaces</td>
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<td>Distinguishing between different functions</td>
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<td>Vertical movement elements</td>
<td>Provide touchless elevators</td>
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<td>Increased no. of vertical movement elem.</td>
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<td>Adequate space for social distancing</td>
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<td>Allocate one-way stairs for movement</td>
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<td>Clarity of location within floors</td>
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<td>Installation of indicative signs</td>
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<td>Spatial suitability for circulation (PI.1.3)</td>
<td>Permeability</td>
<td>Connectivity between spaces</td>
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<td>Wayfinding</td>
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<td>Accessibility</td>
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<td>Main Categories of (PI.)</td>
<td>Sub-categories of (PI.)</td>
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<td>Preventive Solutions</td>
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<tr>
<td>Indoor Air Quality (PI.2)</td>
<td>Level of natural ventilation (PI.2.1)</td>
<td>Passive design strategies</td>
<td>Perfect orientation of the building</td>
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<td>Use cross ventilation</td>
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<td>Use stack ventilation</td>
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<td>Use of windbreaks</td>
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<td>inner courtyards</td>
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<td>The perfect design for exterior openings</td>
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<td>Ventilation Type</td>
<td>Natural or hybrid ventilation</td>
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<td>Direction of airflow</td>
<td>One-way indirect flow</td>
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<td>Source distribution pattern</td>
<td>Linear or Networked Distribution</td>
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<td>Mechanical Filtration technologies</td>
<td>High-Efficiency Filters (HEPA)</td>
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<td>Natural Filtration technologies</td>
<td>Green Wall (Natural Plants)</td>
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<td>Disinfection techniques</td>
<td>Bipolar Ionization Technology (NBPI)</td>
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<td>UVGI (Type C) technology</td>
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<td>Non-Thermal Plasma Technology (airPHX)</td>
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<tr>
<td>Indoor Environmental Quality (PI.3)</td>
<td>Maximise natural lighting (PI.3.1)</td>
<td>Passive design strategies</td>
<td>Perfect orientation of the building</td>
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<td>The perfect design for courtyards</td>
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<td>Employing reflective interior surfaces</td>
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<td>Important spaces near exterior windows</td>
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<td>Employing reflective lighting systems</td>
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<td></td>
<td>Improve mental health (PI.3.2)</td>
<td>Design elements of therapeutic environments</td>
<td>Increasing natural outdoor spaces</td>
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<td>Provide windows with outdoor views</td>
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<td>Large and purposeful balcony design</td>
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<td>Use of elements, materials and natural colours</td>
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<td>Privacy and Personal Spaces</td>
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<td>Control and Prevention Engineering (PI.4)</td>
<td>Proper selection of indoor materials (PI.4.1)</td>
<td>Internal and external surfaces</td>
<td>Use of smooth surfaces</td>
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<td>Use of interchangeable surfaces</td>
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<td>Use of healthy and sustainable materials</td>
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<td>Use of cleanable materials</td>
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<td>Reduce the angles of the inner edges</td>
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<td>Self-cleaning spaces (PI.4.2)</td>
<td>Provision areas for sterilization devices</td>
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<td>Provision of sterilization and hand-washing equipment</td>
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<td>Installation of indicative marks for sanitizing common tools</td>
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<td>The multiplicity of bathrooms within the building’s floors</td>
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<td>Provision of space for solid and contaminated waste</td>
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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. Hamed 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 be-
fore 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 (Pannee 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 (P.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).

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)

<table>
<thead>
<tr>
<th>Main Categories of (P.I.)</th>
<th>Sub-categories of (P.I.)</th>
<th>Potential Problems</th>
<th>Proposed Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P.I.1) &amp; (P.I.2)</td>
<td>Poor physical segregation</td>
<td>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.</td>
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<tr>
<td>(P.I.1)</td>
<td>Limited provision of safe distance implementation requirements</td>
<td>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.</td>
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<tr>
<td>(P.I.1)</td>
<td>Low level of spatial suitability for circulation</td>
<td>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.</td>
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<tr>
<td>(P.I.1.3)</td>
<td>Clear limitations of the ability to expand indoor spaces</td>
<td>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.</td>
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<tr>
<td>(P.I.2.1)</td>
<td>Poor orientation of the building</td>
<td>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.</td>
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<tr>
<td>(P.I.2)</td>
<td>Limited use of purification techniques</td>
<td>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.</td>
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<tr>
<td>(P.I.2.2)</td>
<td>Not using design standards</td>
<td>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.</td>
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<tr>
<td>(P.I.3.1)</td>
<td>Limited use of internal treatments</td>
<td>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.</td>
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<tr>
<td>(P.I.3)</td>
<td>Non-employment of therapeutic environments design elements</td>
<td>The research suggests using natural elements within spaces, using natural materials and colours, and reusing balconies overlooking landscapes.</td>
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<tr>
<td>(P.I.4)</td>
<td>Improper selection of materials and finishes</td>
<td>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.</td>
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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).

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 recom-
mended 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.


Allam, Z., & Jones, D. S. (2020). Pandemic strike 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


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