

Paper Type: Original Article

Critical Architectural Design Indicators for Mitigating the COVID-19 Pandemic

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Citation:

Received: 14 September 2024

Revised: 10 November 2024

Accepted: 03 January 2025

Ghasemi, S., & Seddigh, M. (2025). Critical architectural design indicators for mitigating the COVID-19 pandemic. *Architectural dimensions and beyond*, 2(2), 78-90.

Abstract

The outbreak of the novel coronavirus (COVID-19) was first identified in December 2019 in Wuhan, Hubei province, China, with an unknown origin. As the global community grapples with the pandemic and faces ongoing challenges related to vaccine access and viral mutations, safeguarding human health has become increasingly prominent. In such circumstances, the home-the primary refuge from external threats-is critical in individual and public health. This research investigates the potential of architectural design to contribute to pandemic resilience and promote health. It raises the central question: How can the built environment mitigate the impacts of COVID-19 and support human wellbeing? To address this, a theoretical review of interdisciplinary literature in architecture, health, and pandemic response was conducted to identify influential environmental factors. These factors were further analyzed using SPSS-based statistical methods to prioritize their significance in design practice. The study identifies several key design elements that are heightened during pandemics: Adaptable and multifunctional furniture, spatial layout planning, material selection, smart technologies, integration of plants, natural ventilation, access to natural and artificial lighting, circulation paths, color schemes, and visual connectivity. Emphasizing these elements can contribute to healthier living environments in line with World Health Organization (WHO) health standards during public health crises. The findings underscore the role of architecture not only in sheltering but also in actively enhancing human resilience against pandemics.

Keywords: COVID-19, Pandemic, Health-oriented architecture, Environmental psychology.

1 | Introduction

In the current global situation, where the world is still grappling with the COVID-19 pandemic and facing challenges related to vaccine distribution-particularly due to the virus's continuous mutations-the importance of health has become increasingly significant. As observed, the first line of human defense against harmful agents such as this virus is retreating to shelter [1].

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Housing, as one of the most fundamental human needs-even at its most basic definition as a form of shelter-has posed numerous challenges for humanity in meeting this essential requirement. The importance of this issue is reflected in the constitutions of many countries; for instance, article 31 and paragraph 1 of article 41 of the constitution of the Islamic Republic of Iran emphasize the right to housing. Housing has been defined not merely as a residence but also as a space for peace, rest, and healthy living-far from the stress of work and daily activity. It is regarded as a place of dwelling and belonging, far beyond a purely physical shelter and a setting equipped with the necessary facilities for better living [2].

Given its broad dimensions, neglecting or underestimating human needs inevitably leads to decreased quality of life within residential environments. Housing is deeply interconnected with architecture, society, and culture, significantly influencing residents' psychological wellbeing and social interactions [3]. Furthermore, in the three key physical, psychological, and social health domains, housing plays a crucial role in providing security and comfort [4].

Humanity's most important goal across all domains has been to enhance the quality of life. Throughout history, all human endeavors, advancements, and achievements have, in one way or another, aimed at fulfilling this objective. Therefore, one of the primary missions of architecture and environmental design has been to create appropriate settings for human presence and to improve life quality. Moreover, the relationship between architectural quality and quality of life can be evaluated through the lens of health [5].

2 | Background

Sever and Akbulak [6], in their study titled "the effects of the concept of minimalism on contemporary architecture: Expectations after the COVID-19 pandemic", using content analysis methodology, argue that the pandemic has introduced new constraints and regulations for the design, construction, and implementation of built structures.

Butaib and Alsubban [7], in their research "emerging lifestyles after COVID-19: Housing flexibility as a fundamental need for apartments in Jeddah", employed theoretical studies and targeted interviews. Their findings suggest a significant gap between user satisfaction and spatial quality during the pandemic.

Alraouf [8], in the study "new normal or forgotten normal: Challenging the impact of COVID-19 on contemporary architecture and urbanism", using literature review and interviews, concluded that despite the necessity of social distancing during pandemics, maintaining social cohesion remains critically important.

Pfeffer et al. [9], in their study "stress research during and beyond the COVID-19 pandemic", emphasize that current technological advancements should implement various adaptations in experimental protocols.

Awada et al. [10], in their research "ten questions concerning occupant health in buildings during normal operations and extreme events including the COVID-19 pandemic", state that the design of interiors and micro-spaces must receive increased attention due to their significant impact on occupants' health.

Alhousban et al. [11], in the study "how the COVID-19 pandemic is changing the future of architectural design", using theoretical methods, claim that architecture has effectively become a medical discipline, offering a means of controlling the spread of the disease.

3 | Theoretical Foundations

3.1 | COVID-19

The coronavirus was first observed in December 2019 in Wuhan, Hubei Province, China, and has an unknown origin. Initial investigations and subsequent research revealed that the virus is related to SARS-CoV, which is why it was named "severe acute respiratory syndrome Coronavirus" (SARS-CoV-2). The global spread of the virus and the resulting thousands of deaths led the World Health Organization (WHO) to declare it a pandemic on March 12, 2020. The fatalities and damages caused by the disease continue to this

day. Based on observations and experiences so far, patients with this illness exhibit a wide range of symptoms, from mild to severe, and in some cases, even asymptomatic. The most common symptoms reported include fever (83%), cough (82%), and shortness of breath (31%). Gastrointestinal symptoms such as vomiting, diarrhea, and abdominal pain have been reported in 2 to 10 percent of cases. Studies show that the primary target of the virus is the lungs. Still, other organs are not spared, including the cardiovascular system, gastrointestinal tract, kidneys, liver, central nervous system, and eyes [12].

In most countries, the outbreak of COVID-19 occurred suddenly and unexpectedly. The mutation and spread of this disease are unpredictable, and this unpredictability causes numerous problems in terms of safety and security. Quarantine and social distancing-initial strategies adopted by governments-may lead to mental health issues in addition to physical harm, including social isolation, loneliness, depression, physical inactivity, and more, even among previously healthy individuals [13].

The mortality rate and complications of the COVID-19 pandemic continue to change rapidly. As of April 23, 2021, there were 144,367,284 reported cases worldwide, with over 3,066,270 deaths. In addition to the physical effects and various consequences of the disease, which are still under study, the fear of contracting the virus, along with stress, anxiety, and even depression, has significantly impacted the general population [14].

3.2 | Interactions

Following quarantine and the interruption or reduction of contact with the outside environment, alongside other aspects of this pandemic, social interactions, even within the smallest unit of society, the family, experienced significant disruptions, which should be considered one of the major consequences of this virus. For example, in 2020, a study was conducted regarding terraces and balconies and the extent and frequency of their use during the COVID-19 pandemic. The results indicated increased use for various reasons, including the need for interaction and communication during the pandemic [15].

Additionally, another study in 2021 proved the need for communal spaces, such as parks and streets, to maintain a connection with the outside environment and foster a sense of community. This study examined the role of architecture and smart structures [16].

Moreover, the impact on various social groups during this period was examined. Children and young people were found to be the most vulnerable groups in coping with the psychological aspects of the virus, as their need for interaction and communication was stronger. Following them, young women were more affected by mental health issues compared to young men, and mothers with young children faced even greater challenges. To improve their wellbeing, suggestions such as social connections and physical activities were proposed [17].

Social integration and the human desire for social interaction in a collaborative housing project in Sweden were also researched. The residents, including elderly individuals, local youth, and refugees, were studied regarding their experiences before and during the pandemic. The results indicated that during this time, a sense of emptiness emerged among the residents, and they sought to create social bonds and interactive bridges. The residents shared communal spaces, including sports facilities, to foster social interactions [18].

3.3 | Architecture and Health

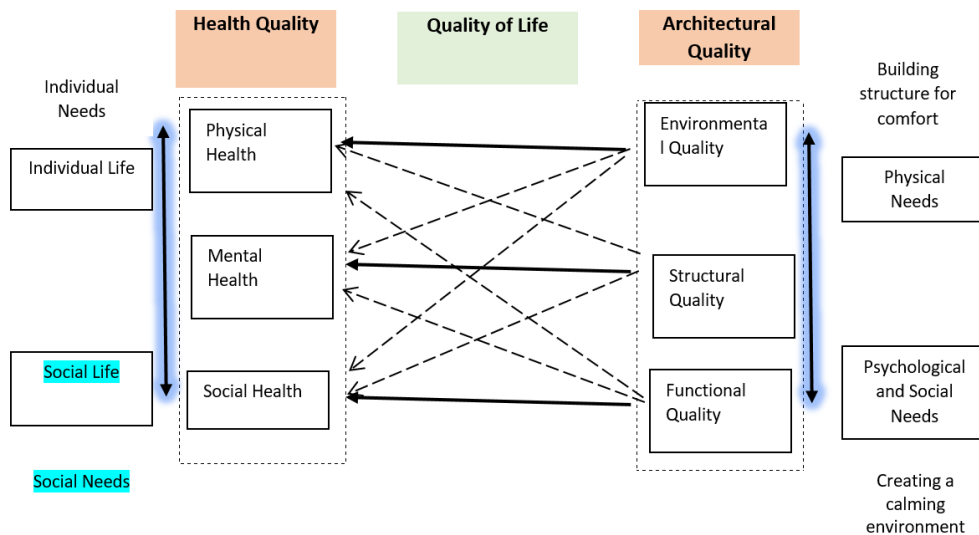


Fig. 1. Final model of the research regarding the relationship between architectural quality, quality of life, and health dimensions [5].

4 | Method

As shown in Fig. 1, architecture can play a fundamental role in ensuring security and comfort in the three dimensions of quality of life: physical, mental, and social health. Due to the importance and human focus on health, numerous studies have been conducted to identify the factors that influence it, and architectural researchers have not lagged, conducting many studies in this area every year. As a result, the impact of the environment on health has been proven through various methods.

For example, a 2018 study used a crowdsourcing experiment and observed 400 users to identify the architectural design features immediately felt upon entering a space and influence the users [12].

Even on a smaller scale, a study was conducted on Finnish youth's perception and the impact of wooden interior materials, where the difference in the effects, the feeling of relief, comfort, and wellbeing, depending on the type of wood and even the amount of money spent on the wood, was significant [19].

Regarding the impact of architecture on health, materials used in construction can be discussed, and numerous examples are seen in the modern world. One recent effort includes research and testing to create a Copper-Tungsten-Silver alloy additive against SARS-CoV-2, conducted in 2021 to reduce disease transmission through surfaces [20].

Also, a study in Brazil in 2021 tested the relationship between the built environment and patient health through qualitative assessments, investigating the role a structure can have in disease transmission or improving the condition of its users. The most notable finding was the potential disease transmission through the openings' surfaces [21].

Given the nature of the COVID-19 virus and its psychological, physical, and social impacts, we must now focus on how these impacts manifest and identify the environmental elements that can enhance and influence these factors within buildings.

5 | Findings and Analysis

In the first stage, using previous research, we will review all the studies and experiments conducted on the topics under discussion, namely, the COVID-19 pandemic, its individual and social aspects, environmental psychology, and health-related architecture. Researchers who have investigated these topics have targeted various issues, examined their significance, and provided proof of their importance.

The method of influence and interaction between the environment and humans has always been a subject of discussion. However, due to the pandemic, such as COVID-19, these studies were examined in more detail, and of course, research will continue as the understanding of the disease progresses. According to the previous research study in *Table 1*, the extracted findings are summarized as follows.

Table 1. No caption.

Number	Article Title	Component	Indicator	Year of Publication
1	Emission of pollutants from building materials and their impact on indoor air quality and employee performance in offices	1. Building materials 2. Suitable furniture [22]	Spatial quality	2005
2	Principles of designing narrow urban houses: For affordability and adaptability	1. Affordable 2. Open plan and layout 3. Color 4. Floor-to-ceiling height 5. Openings 6. Closet 7. Multifunctional furniture 8. Creativity [23]	Spatial quality	2012
3	Towards quantifying the human experience in the built environment: A crowdsourcing-based experiment to identify influential architectural design features	1. Open plan (Spatial layout) 2. Natural ventilation 3. View 4. Natural light 5. Space flexibility in partitioning 6. Artificial light 7. Space density 8. Color [12]	1. Spatial quality 2. Health	2018
4	Indoor air quality: A review of building design strategies and regulations in post-pandemic architecture	1. Mechanical ventilation 2. Natural ventilation 3. Green walls and microalgae [24]	Spatial quality	2020
5	The impact of minimalism on contemporary architecture: Post-COVID-19 expectations	1. Materials 2. Efficient furniture 3. Layout and optimal Space [6]	Spatial quality	2020
6	Questioning the use of balconies in apartments during the COVID-19 pandemic	1. Multifunctional terrace and balcony 2. Its dimensions 3. Ventilation 4. Natural light 5. Storage 6. Touchless and smart elements 7. Disinfection upon entry [15]	1. Interaction 2. Health	2020
7	Emotional responses to 3D virtual reality-based spaces: Focusing on ECG response to single-occupancy housing with different layout configurations	1. Space layout 2. Spatial relationships 3. Spatial elements 4. Entrance 5. Furniture 6. Lighting 7. Color [25]	1. Spatial quality 2. Health	2020

Table 1. Continued.

Number	Article Title	Component	Indicator	Year of Publication
8	Human stress response in office environments with wooden furniture, specifically	1. Materials 2. Furniture 3. Wood 4. Color 5. Light [26]	1. Spatial quality 2. Health	2020
9	designing a safety pathway for patients unaffected by covid-19 during the sars-cov-2 pandemic in an italian university hospital	1. Spatial layout 2. Entrance separation 3. Temperature 4. Entrance access to the outdoors 5. Entrance access to plants [27]	1. Health 2. Spatial quality	2020
10	Emerging lifestyles post-COVID-19: Housing resilience as an essential need for apartments in Jeddah	1. Flexibility 2. Plants and garden 3. Furniture 4. Spatial layout [7]	Spatial quality	2020
11	Finnish youth's perception of health, wellbeing, and sustainability of wooden interior materials	1. Materials 2. Furniture [19]	Spatial quality	2020
12	Making the case for smart buildings in preventing coronavirus: Focusing on maintenance management challenges	Smartization [28]	Spatial quality	2020
13	Viruses in the built environment: Meeting report	Smartization [29]	1. Health 2. Spatial quality	2020
14	Smart technologies and design for healthy built environments	1. Smartization 2. Materials 3. Natural ventilation 4. Mechanical ventilation 5. Lighting 6. Temperature 7. Humidity 8. Color [30]	1. Spatial quality 2. Health	2020
15	The built environment with antivirus: Lessons learned from the COVID-19 pandemic	1. Nature 2. Low overall height (Number of floors) 3. Smart features 4. Optimal ventilation [24]	1. Spatial quality 2. Health	2021
16	A framework for social distancing monitoring using deep learning architecture to control the transmission of the COVID-19 pandemic infection	1. Unconscious human behavior 2. Optimal layout and space 3. Shared gathering space [31]	1. Health 2. Spatial quality	2021
17	New normal or forgotten normal: challenging the impact of COVID-19 on contemporary architecture and urban planning	1. Multifunctional furniture 2. Plants 3. View and landscape 4. View of busy areas like streets 5. Shared space 6. Access path [8]	1. Spatial quality	2022
18	The impact of the prolonged COVID-19 pandemic on stress resilience and mental health: A critical review across waves	1. Stress 2. Individual characteristics [17]	1. Health 2. Interaction	2023

Table 1. Continued.

Number	Article Title	Component	Indicator	Year of Publication
19	Stress research during the COVID-19 pandemic and beyond: An examination of stress parameters	1. Stress 2. Environmental adaptability and flexibility [9]	1. Health 2. Spatial quality	2021
20	Ten questions about occupant health in buildings during normal operations and extreme events, including the COVID-19 pandemic	1. Environmental sensor 2. Physiological sensor [10]	1. Spatial quality 2. Health	2021
21	The role of the built environment in updating design requirements in the post-pandemic scenario: A case study of selected diagnostic facilities in Brazil	1. Touchless equipment 2. Warm lighting 3. Acoustic materials 4. Distraction elements 5. Nature 6. Green roof 7. Wooden furniture [21]	1. Spatial quality	2022
22	Towards a healthy home: Examining the flow of food and changes in interior spatial functioning during the COVID-19 pandemic	1. Spatial layout 2. Nature 3. Light 4. Natural ventilation [32]	1. Spatial quality	2022
23	How the COVID-19 pandemic will change the future of architectural design	1. Materials 2. Natural ventilation 3. Furniture 4. Smart equipment 5. Cooling and heating 6. Spatial layout 7. Plants 8. Green roof 9. Light 10. Transparency [11]	1. Spatial quality	2021
24	Development of a Copper-Tungsten-Silver alloy additive against SARS-CoV-2	Materials [20]	Spatial quality	2021
25	social integration through social interaction in daily life: Residents' experiences during the COVID-19 pandemic in the SallBo cooperative housing, Sweden	Common areas [18]	1. Spatial quality 2. Health 3. Interaction	2021
26	The role of smart architectural elements in reducing the impact of the pandemic in residential complexes	1. Smart features 2. Spatial layout 3. Isolation room 4. Food storage room 5. Shared gathering space 6. Nanotechnology materials [16]	1. Interaction 2. Health 3. Spatial quality	2021
27	Architecturally safe and healthy classrooms: A medical and environmental approach to achieving sustainability in light of the global COVID-19 pandemic	1. Antibacterial coating (Material) 2. Antiviral coating (Material) 3. Space area and size 4. Floor-to-ceiling height 5. Up-to-date materials 6. Multifunctional furniture 7. Movement path [33]	Spatial quality	2021
28	Occupants' health in buildings: The impact of the COVID-19 pandemic on building experts' opinions and its implications for research	1. Heat 2. Artificial light 3. Natural light 4. Antibacterial curtain fabric 5. Stress 6. Environmental wellbeing and comfort 7. High ventilation [34]	1. Spatial quality 2. Individual 3. Health	2022

According to these studies, many researchers have examined various aspects of the environment, human spatial quality, human interactions, and individual health. However, each approached these topics with its own unique perspective and under different yet aligned conditions, focusing on different aspects and analyzing them.

Based on their findings, as shown in *Figs. 2-4*, the subcategories considered or proven in their research are more specifically highlighted. As we can see, common themes such as view and landscape appear as a primary criterion. However, a closer look reveals that, on the one hand, the view of nature is aimed at achieving calmness and reducing stress. On the other hand, the view of areas with the movement of other people is intended to alleviate the sense of isolation caused by quarantine during the COVID-19 pandemic. Therefore, each aspect should be understood in terms of its purpose to ensure it is correctly implemented in design.

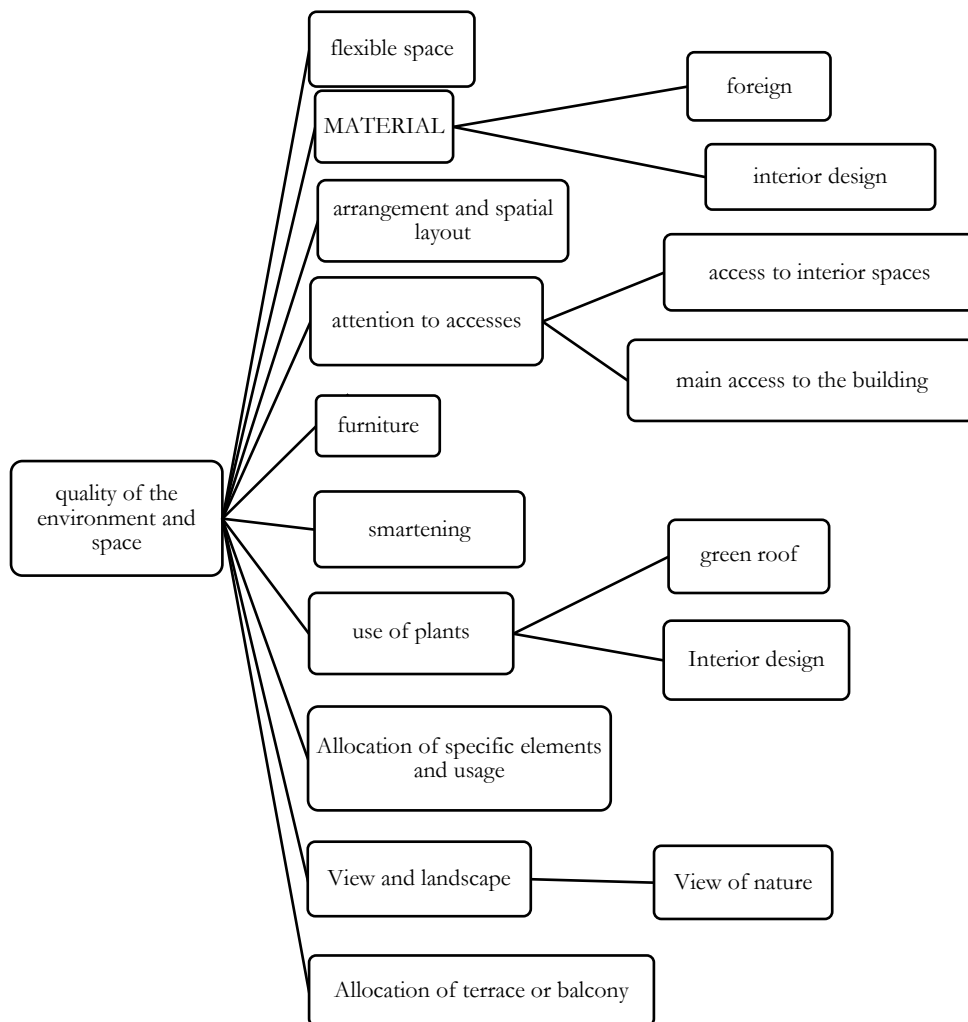


Fig. 2. Type and relationships of key components of environmental and spatial quality indicators.

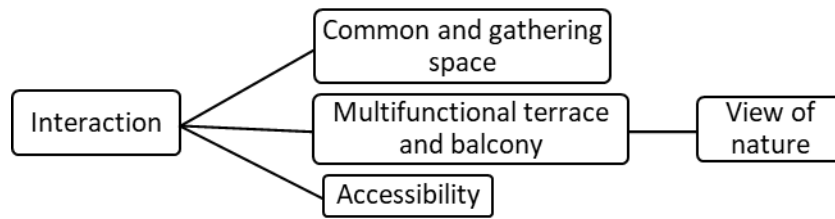


Fig. 3. Type and relationships of key components of interaction indicators.

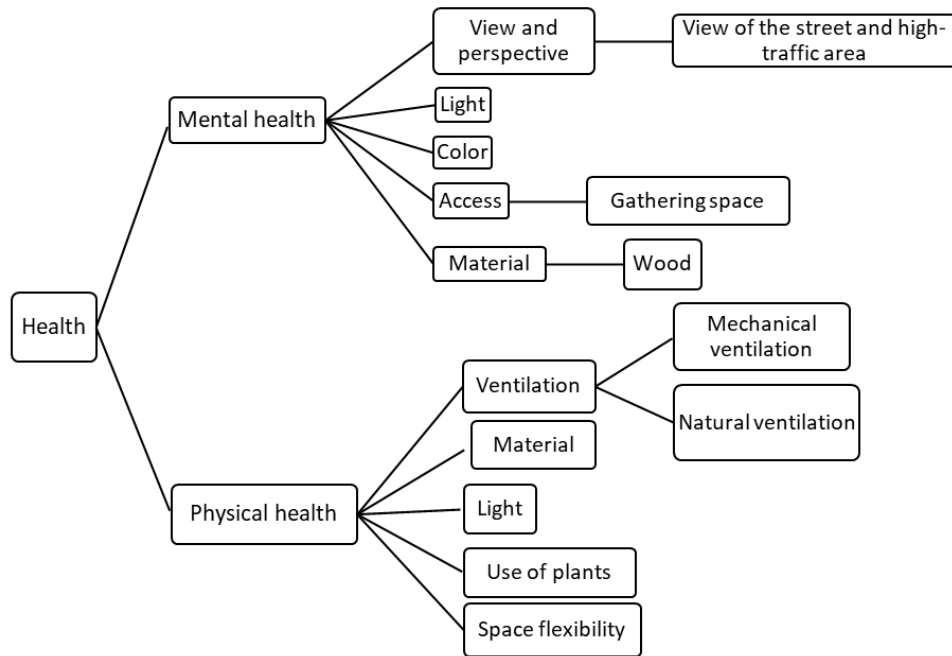


Fig. 4. Type and relationships of key components of health indicators.

After collecting the relevant data, we will frequently analyze them in recent studies and identify the most significant findings researchers have discovered in pursuit of this goal through various topics in their research. Fig. 4 clearly illustrates this analysis, showing the following most frequently occurring components.

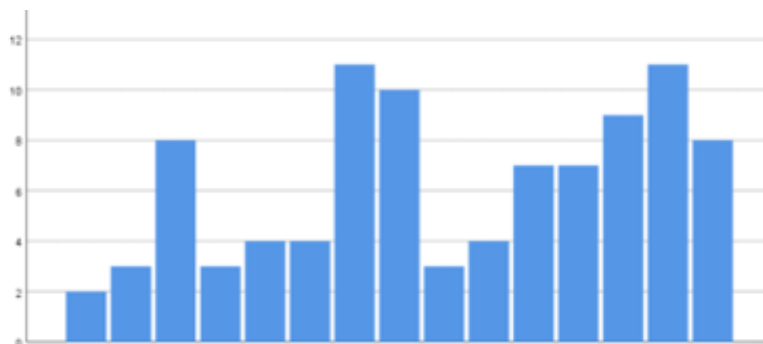


Fig. 5. Most frequent components in the reviewed studies.

Horizontal indicators

From left to right, height, terrace, ventilation1, ventilation2, view, color, furniture, material, area, access route, natural light, artificial light, smart features, plan, plants.

Vertical indicator: Repetition

Based on the gathered data and the chart drawn from them, the components were identified in order of frequency and importance as follows:

Flexible and multifunctional furniture

Considering the frequency of its repetition, having multi-purpose and flexible furniture is very important in such specific conditions. During quarantine, a space takes on multiple functions due to some members becoming ill and reduced movement. Therefore, multifunctional and flexible furniture means having the capability to be used for daily activities, entertainment, work, and expanding or gathering for easier interaction to create more distance between members, which can be impactful.

Space Layout

The next important component is the layout of the space and the correct placement of areas depending on the conditions of the COVID-19 pandemic. The degree of openness of the space and the proximity of different sections, which may have been seen as a positive feature before the pandemic, now need to be reconsidered. In this period, the arrangement of spaces-such as placing service areas and bathrooms near the entrance for disinfection, placing kitchens near the entrance along with open or semi-closed spaces like a terrace to reduce the spread of disease during disinfection, and the arrangement of private and public spaces with the ability to expand or separate when needed-becomes crucial. Furthermore, the layout of the plan based on proper climatic orientation to reduce energy consumption, considering the increase in energy use due to building automation, has gained more importance.

Materials

The materials used in constructing a building, regarding their compatibility with the climate in terms of energy and the addition of antibacterial and antiviral coatings on floors and walls, as well as paying attention to the materials of the furniture considering their psychological impact on users (such as the difference in the effect of wood, which is also dependent on other environmental elements like light), must also be considered. The impact of materials on human health has been proven in many studies, and the COVID-19 pandemic is no exception. Therefore, these factors should receive more attention.

Smart building technologies

Smart building technology has gained attention across all fields today. Still, during a pandemic, due to the nature of the COVID-19 virus and its easy transmission through surfaces, efforts to minimize touch by using non-touch equipment and openings help control its spread. Using thermal and temperature sensors to control the environmental temperature and that of humans to maintain health and prevent excessive temperature fluctuations has made smart building technology even more significant.

Plants and natural ventilation

The use of plants and nature within interior spaces, such as placing plants between private and public spaces, using green walls, locating plants in terraces or balconies for visual and psychological satisfaction and even air purification, and also providing a small space for growing essential crops during the pandemic, positively affects users' health. Apart from their health and hygiene benefits, their presence offers positive distractions. Natural ventilation through the design of part of the space as open or semi-open to enhance indoor air quality through circulation and fresh air intake from outside becomes necessary to ensure users' health, primarily since this virus targets the lungs.

Natural light and artificial light

Benefiting from natural sunlight alongside using artificial light in appropriate amounts and quality significantly impacts users' mental and physical health in any condition. Given the psychological effects of quarantine, the presence of natural lighting in the building in various designs (openings, skylights, balconies, etc.), the quality and intensity of artificial lighting, and the integration of warm light are crucial during this period.

Access paths, colors, views

According to studies, disease control can be better managed at the initial entry and in hallways leading to the interior and various building sections. For example, the separation of infected and healthy people can be achieved by creating multiple access points to the building, providing direct access to a space for disinfecting purchased food and storing necessities during the pandemic, preventing contamination from entering the main living space, creating a disinfection area for users at the entrance, and making the access paths longer to reduce the fear of contaminating the indoor environment.

Having a view of nature, bustling streets, and the urban environment contributes to positive distraction and reduces the effects of depression, helping maintain a sense of community. While the concept of comfort and relaxation has changed after the pandemic, the view of a busy urban space, unlike before, now reduces stress and psychological damage caused by isolation. Additionally, using the correct color, emphasizing light colors in the environment, and interior décor can significantly reduce adverse psychological effects in isolation and quarantine, alongside other design elements that promote mental health.

6 | Conclusion

The COVID-19 virus is a major global topic, and its spread is similar to the 1918 influenza. WHO declared this disease a pandemic in March 2020. The rapid spread of this respiratory virus, which is transmitted through airborne particles and contact with surfaces, has posed a significant challenge to the world. As a result, experts and researchers in all fields are seeking ways to help humanity fight this disease. Looking at similar historical events, we can observe that humanity's first defense against such challenges is seeking refuge in shelter and housing. Therefore, the role of architects and designers in creating safe spaces from various perspectives is clear. This research aimed to identify the most important elements required to create a flexible and safe environment that ensures physical, mental, and social health. In this regard, we studied research on this subject and similar topics. We extracted the key factors and, using charts in SPSS, identified the variables that were emphasized the most. These variables include materials, spatial layout, access, and other factors, which can help designers define an optimal framework in the event of a pandemic or similar situations in the future.

7 | Limitations

Numerous studies have been conducted regarding the COVID-19 virus, and this research is based on the information available thus far. A more comprehensive examination will be possible once more details about the virus are known over time.

Conflict of Interest

The authors declare that they have no conflict of interest regarding the publication of this manuscript.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Funding

This research received no external funding.

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