Sustainability Requirements of Residential Buildings

Subjects: Construction & Building Technology

Contributor: Aidana Tleuken

The COVID-19 pandemic is bringing about changes, and alongside these, we can alter the way we design our living spaces. The need for a healthy and comfortable living space is essential to mental, physical well-being, and personal comfort. This entry shows how is COVID-19 Experience Transforming Sustainability Requirements of Residential Buildings.

Keywords: COVID-19 pandemic ; housing ; residential buildings ; SARS-CoV-2 ; sustainability requirements

1. Introduction

December 2019 marked the beginning of a novel disease outbreak, later called COVID-19 by the World Health Organization (WHO) [1]. Epidemiological links led the virus origins to animal stock in Wuhan [2]. Taking into account that some previous disease outbreaks have also been zoonotic (originating from animals), such as SARS (Severe Acute Respiratory Syndrome) in 2003 and MERS (Middle East Respiratory Syndrome) in 2012, researchers claim that the amount of novel zoonotic diseases is expected to rise in the future [2][3]. For instance, markets that sell meat and products from wild animals are still not prohibited and thus continue to exist globally. This indicates a still ongoing threat of new disease outbreaks of animal origin. In addition, some researchers forecast a rise of zoonotic diseases, linking them to climate change and extensive land usage for agriculture and construction of infrastructure, as these activities put stress on the wildlife by reducing their habitat zones [3]. Finally, existing land-use practices lead habitats of humans and domestic animals to be brought closer to wild animals, which eases the way of virus mixing and further propagation [2]. COVID-19, caused by SARS-CoV-2, has progressed to become a global pandemic, and, in contrast to previous pandemics, it caused a global-scale crisis in medical systems and business [1]. The COVID-19 pandemic has so far created a tremendous impact on humanity's both personal and professional aspects.

Possible means of contagion propagation and their lifespan in different mediums are still being researched. Recent studies show that one of the transmission means is air in human-to-human interaction, and SARS-CoV-2 is able to suspend in the air for up to four hours [4]. Another means of propagation is to deposition the virus on the surfaces after direct contact with an infected person or indirectly via turbulent flow. The lifespan depends on the medium matter, e.g., steel surfaces allow the virus to survive up to three days [4][5].

In a short time, rapidly propagating COVID-19 has forced people to spend most of their time at home to prevent the risk of viral spread [5]. The world needs to adapt quickly to such changes in lifestyle and to bear with strict safety measures. Remembering recent outbreaks of other diseases, COVID-19 is another vivid reminder of the danger of unknown diseases uprising [2]. The experience of quarantine life due to the COVID-19 pandemic continues to transform the perception of the environment in different ways. Dense spaces will no longer be as welcomed, as they increase virus transmission routes. As such, to improve social distancing, public spaces have been (and are still) suspended worldwide.

In addition to the impacts detailed above, offices, universities, and schools remain closed in some locations, necessitating people to work and study from home [6]. Therefore, residential buildings have become a crucial infrastructure type, vital for sustaining these disrupted communities [5]. Housing is becoming more than just a living space, which also significantly increases buildings' resource consumption (e.g., electricity and water). Therefore, even with the relief of the COVID-19 pandemic, the current world we live in still needs to acquire changes to become more resilient to possible upcoming disease outbreaks and lockdowns, and it introduces challenges to the existing residential buildings for adaptation to a new reality. To ensure that we remain resilient and sustainable, future houses need to be able to answer questions under epidemic measures, such as (1) how to effectively avoid disease propagation, (2) how to minimize the environmental effect, and (3) how to maintain and improve the comfort of people spending most of their time at home.

2. Impact of COVID-19 on General Society and Urban Environment

Before COVID-19, various other diseases have shaped our environment, including city planning and residence interiors, and there were several developments in architecture and urbanization in the last two centuries. Historically, the bubonic plague that happened in the 14th century facilitated the urban development of the Renaissance. More recently, the 20th century's challenges, including overcrowded cities with tuberculosis and various flu types, motivated architects and urbanists of that time to make changes such as clearance of slums, reforms of tenements, and waste management. As another example, smooth, straight, and wide streets for proper underground pipe system installation were developed due to cholera and typhoid outbreaks during the industrial era [7]. Recently, COVID-19 has drawn many researchers' attention from various fields and thus become one of the most frequently studied topics. The previous studies mainly discussed how COVID-19 influenced multiple aspects of our life, including economic factors [8], sustainable development goals [9][10], food pathways [11], education [12], tourism [13], urbanization [7], living spaces [14], and business [10].

Filho et al. [9] reported that COVID-19's economic impacts are unexamined and only going to unfold; the global economic downswing is estimated to be more challenging than the financial crisis of 2007–2009. According to the United Nations Trade and Development Agency (UNCTAD) [14], the consequences of COVID-19 are going to cost the global economy in 2020 around one trillion USD, considering that the length of the pandemic is ambiguous. Consequently, a global economic collapse is expected to have harsh consequences, including food shortages and hunger. Blay-Palmer et al. [11] stated that the right to food should be guaranteed under international law to fulfill the obligations of all governmental levels. New policies tackling the food shortage and hunger should be based on a clear understanding and consideration of the human right to food. Tran et al. (2020) [12] examined the impact of the COVID-19 experience on Vietnamese students' education. The study concluded that there is a significant difference in students' learning routines from different types of schools. Learning capabilities, motivation, and self-discipline play crucial roles in distant learning during the pandemic. Additionally, family income partially influences the efficiency of students' learning in pandemic conditions such that above-average income group students spent less time in offline learning compared to their other peers.

Regarding the impact of the pandemic on business, compared to the Great Depression or the housing recession in national economies (2008), the significant difference of COVID-19 is that it influenced both the supply and the demand side of the economy. Future business is going to be significantly more digitalized, which will bring positive changes, including cost-cutting, increased business intelligence, and more transparency [10]. Digital transformations are expected to occur in all daily activities. Apart from the digitalization of business, most employees have to be ready to host online meetings and to work with new portable types of equipment for virtual communication [15].

It is expected that the COVID-19 pandemic experience will slow down urbanization. Villages and city suburbs will likely gain more attention to be enhanced and experience necessary digital transformations. Moreover, cities are advised to expand horizontally and decrease their densities. Various services, including health facilities, schools, and shopping malls, are better if they are decentralized, putting more attention on smaller units. Urban farming will likely be one of the critical aspects of creating a self-sustaining community [7][8][16][17]. Additionally, cities are expected to transform from car-driven to more walkable and cyclable, which is advantageous over cars by being environmentally friendly as well as beneficial for the physical and mental health of citizens [18][19]. Office spaces are also expected to experience necessary changes, with larger spaces having fewer seats, to ensure the new requirements of social distancing [20][21].

The COVID-19 pandemic experience will also influence strategies for building construction. Modular construction will gain more popularity, because it allows the construction of various building types quickly with lower expenses [22]. Standardized prefabricated components of modular construction strategy will allow us to adapt to and meet healthcare buildings' requirements during quarantine times [23]. Adaptive reuse of existing structures is one of the possible ways to meet the demands for emergency facilities. In case of a sudden pandemic, big spaces such as sports facilities and fields, parking lots, and other open space buildings could be converted into temporary medical facilities or hospitals. Future buildings will be designed considering the opportunity for efficient, flexible, and quick transformation of the building for necessary needs (hospitals, medical facilities, etc.) [24]. Lightweight and adaptable structures have advantages such as construction speed and portability. Temporary structures that can be easily disassembled and transported as field hospitals are being designed for use during COVID-19-like pandemics [24][25]. Post-pandemic architecture may also include hygienic building materials that are easy to be sanitized [20][26].

Apart from the impacts in general society and the urban environment, as mentioned above, a new set of requirements and suggestions are emerging regarding building design. This suggests a drastic paradigm change from "business as usual" to "for a pandemic" in the design and operation of buildings, particularly for residential buildings. The building design will experience various changes starting from general construction methods to the planning of its details [27][28]. Megahed and Ghoneim [7] highlighted some significant changes that are expected to happen in future architecture approaches,

promoting self-sufficient strategies and refocusing on green space and low-rise buildings with better indoor air quality. An autonomous design of a building is especially crucial during pandemic conditions when the transportation of food and other goods are limited [29][30]. While interaction with green spaces positively influences people's mental health and allows them to grow food during self-isolation time, at the same time, low-rise buildings and resulting better air quality will enable the reduction of density of people as well as the risks of being self-isolated for long durations [31]. Assuming that future buildings are going to experience various transformations, the set of new standards and the design process of new buildings will require a multidisciplinary approach [32]. Significant changes that are going to happen in the design of buildings include greener spaces [13], better air ventilation and intimacy [33], improved water and wastewater management [34], introduction of touchless technologies and antimicrobial materials [35], better solid-waste management [36], social distancing within the house [31], and lightweight architecture and flexible building design [37].

The COVID-19 pandemic forced authorities to oblige people to stay home for disease propagation prevention in many locations. This has abruptly disturbed professional and personal lifestyles all over the world. This leads to the fact that, from now on, homes will be more than just a living place. Consequently, the coronavirus pandemic leads to a reconsideration of existing buildings, which need to become more resilient and sustainable for other possible upcoming disease epidemics/pandemics. The present work aims to define the current sustainability limitations of residential buildings in providing a resilient response to disease outbreaks, and it reviews the emerging solutions and ideas that will lead to "design for a pandemic". The present work addresses the following research questions: (1) how to assess the capacity of existing buildings to protect occupants' health and safety, especially during lockdown periods; (2) evaluating the effect of pandemics on residential buildings' resources consumption; (3) defining the deficiencies of current residential buildings in terms of bringing comfort to the occupants; and (4) addressing emerging solutions and ideas for residential building design that will shift the design paradigm from "business as usual" to "for a pandemic".

3. Search Methodology and Data Collection

The method of data and information collection for the present study was based on a state-of-the-art review [38] of the rapidly growing literature on COVID-19. The speed of information and data flow related to COVID-19 is extraordinary such that an example of such rapidly growing literature on a particular subject has never been previously witnessed. That guided us to a process such that the relevant information was not only collected from scientific literature but also from various high-quality online resources, including blogs, journals, news, policy, and media reports. The available literature was collected from March 2020 (the start of the COVID-19 Pandemic) until the completion of the present manuscript (September 2020). The primary source groups of the study (summarized in Table 1) and the data collection/review were focused on two main categories: (a) lessons learned from the COVID-19 pandemic experience; and (b) its impact on the design of residential buildings. The literature review for the first category mainly focused on the information from Central Asia (which is our expertise area regarding building sustainability), with most findings widely applicable and generalizable to the global context, whereas the second category considered the available information from all around the world. Google and Nazarbayev University Library (with a subscription to 249 databases including ScienceDirect, PubMed, Scopus, and Web of Science) were used as search platforms with some of the keywords used (used individually as well as in combination) including "Effect of COVID-19 pandemic", "Water consumption", "Energy consumption", "Domestic violence", "Central Asia", "Personal comfort during lockdown", "Waste management", "Sustainability of residential buildings", and "Sustainability requirements".

Table 1. Summary of literature review, sources, and information.

Data/Knowledge Source	Type of Information	Database / Source	Literature Found	Subtotal	Total

		ScienceDirect	13		
Nazarbayev University Library	Peer-reviewed research papers	PubMed	25		
		Others	4	51	
	Peer-reviewed research papers	MDPI	5		
		Others	4		
	Policy reports	UN	6		119
		WHO	2	8	
Google	Other reports		6		
	News		19		
	Blogs and Journals		34	60	
	Books		1		

4. Residential Building Sustainability Lessons Learned from COVID-19

The COVID-19 experience has revealed certain deficiencies in current residential building design such that living conditions should be rethought and improved for better resilience through pandemics. More than 90% of infected cases happened in cities, as they have a significant amount of dense and concentrated places [39]. Since multi-story housing is standard in most cities, they need special attention. The sustainability lessons for residential buildings (summarized in Table 2) are presented below as categorized into the following perspectives: (1) health and safety, (2) environment, and (3) comfort.

Table 2. Summary of sustainability lessons learned regarding residential buildings from COVID-19.

Category	Subcategory	Problems	References
Health & Safety	Virus propagation risks	Existing residential buildings have many surfaces of contact (e.g., elevators, doors, ladders), which leads to limited capacity to protect the occupants from virus transmission through surfaces and by air.	[13]
	Domestic violence threat	Lockdowns tend to increase domestic violence frequency, and most existing residential buildings lack any service or facility that could help the victims.	[40][41][42][43][44]
	General health risks	Housings that lack proper comfort can lead to a decline in both physical and psychological health.	[45]

Environment	Energy	Increased energy usage due to global lockdowns (e.g., cooking, the use of ICTs, laundry, entertainment) creates a greater and uninterrupted need for sustainable energy sources.	[46][47][48][49]
	Waste	Households are not ready to manage the possibly infected waste; therefore, there is an emerging need to create a waste separation and disinfection strategy.	[50][51]
	Water	Increased water consumption due to lockdowns might lead to water shortages. It drives a larger necessity for sustainable water management. Wastewater needs to be treated appropriately and sanitized to diminish virus spread.	[52][53][54]
Comfort	Personal comfort	Households lacking comfort (personal space, outdoor space) complicate occupants' lives and lead to health problems (including mental health). Unavailable ICTs lead to a deficient use of necessary services (e.g., medical consultation, food/medicines delivery).	[39][45][55][56]
	Living costs	Due to a sudden drop in economic activity during lockdowns, paying for increasing housing costs becomes problematic for several population classes.	[39][57][58]
	Local services	Lack of independent local stores and pharmacies might create a crisis during lockdowns due to an insufficient amount of necessary reserves in food and medicines.	[11][59]

5. Current Sustainability Requirements

Architects and urban planning institutions are one of the first to respond to disasters such as tsunamis, hurricanes, warfare, earthquakes, and bushfires. They are highly involved in the reconstruction of damaged cities or towns after natural disasters. However, it is surprising that the impalpable calamities, such as pandemics, result in the less active involvement of architects and urban planners. The reason might be that understanding of "disaster" is restricted to only physical natural/anthropogenic types of calamities [60].

One way to push the design of buildings into more sustainable and green approaches and solutions is sustainable assessment tools and guides. The three main components of sustainability are environment, society, and economy, which make a foundation for sustainability assessment tools [61]. Typical categories that are included in the sustainability assessment tool of residential buildings are energy, water, indoor and outdoor environments, site consideration, and material input [62]. Awadh (2017) [63] compared the four most popular and widely used sustainability assessment rating systems: The British Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Global Sustainability Assessment System (GSAS), and Estidama Pearl Rating System. After analyzing all four sustainability assessment rating systems, he concluded that the main priority with the highest weight is given to the energy category in BREEAM, GSAS, and Estidama systems. At the same time, LEED puts into first place the indoor environmental quality category. Among the three major sustainability pillars (environmental, social, and economic), the environmental side is given the most significant attention, while the social pillar is given the least importance in all four sustainability assessment rating systems [63].

Considering the wide range of problems (domestic violence, energy, waste, and water management, food supply, etc.) that have arisen during the COVID-19 pandemic and the inability of current sustainability requirements of residential buildings to tackle those problems, there is a need for reconsideration of current sustainability system and its requirements. Sustainability requirements of residential buildings should be adapted into the new reality with COVID-19-like pandemics, which humanity is going to face for the next decades and even centuries.

6. Major Expected Changes in Sustainability Requirements

Along with the lessons learned from COVID-19, there are changes in sustainability requirements as well, which can be grouped into the following (summarized in Table 3): (1) health and safety, (2) environment, and (3) comfort.

Table 3. Summary of expected changes in sustainability requirements of residential buildings.

Category	Subcategory	Details	References
Health & Safety	Smart technologies	Touchless technologies such as face recognition, voice control, motion sensors, keycard swiping will help decrease the contact with surfaces, which is one of the transmission routes of the viruses.Smart technologies would also allow designing self-cleaning spaces (bathrooms, toilets, etc.).	[7][17][35][64][65][66]
	Indoor finishing materials	Copper and its alloys can effectively kill microorganisms and viruses. Steel and plastic surfaces allow viruses to be active for long durations compared to copper or cardboard surfaces. However, antimicrobial additive for indoor finishing materials should be carefully selected due to the risk of equally being toxic to humans.	[35][65][67][68][69][70][71][72][73][74]
	Green and natural environment	The addition of green spaces into residential building designs will enhance the mental health of residents, decreasing stress, anxiety, and depression during lockdowns. Gardens, where people could grow their own plants, will facilitate the relaxation of residents and increase their psychological well-being.	[13][16][35][75][76][77][78][79][80]
	Indoor air quality, temperature, humidity	Constant air ventilation is essential for maintaining clean indoor air to prevent the spread of the virus. Furthermore, the proper temperature and humidity of the air are critical to the health as well as the comfort of the residents.	[81][82][83]

	Energy	Increased energy consumption due to work from home practices can be controlled via energy-consuming technologies and smart systems, which would increase the efficiency at home.	[47][84][85]
Environment	Solid waste	Increased solid waste, especially personal protective equipment such as masks and gloves, highlighted a need for proper management and disposal of potentially infected waste.	[13][31]
	Wastewater	Since the virus is able to transmit via human feces that contaminate wastewater, there is a risk of its transmission via sewage. Proper wastewater management via additional measures may be needed to avoid the spread of the virus via wastewater.	[13][54][56][86][87]
	Housing automation	Sensors and detectors connected to smart systems would allow us to manage and control the home more comfortably, faster, and smarter.	[13][88][89][90][91]
Comfort	Layout	With the emerging need to work from home, the layout of the rooms is going to likely be different, with more attention paid to the design of comfortable, isolated, and separate workplaces.	[31][60][92][93][94]
	Intimacy	Difficulties in finding some private space during lockdown will shift new housing design towards more private spaces, allowing each family member to have a personal spot at home.	[33][95][96]

7. Conclusions

The current COVID-19 pandemic is bringing different changes to society. It is humanity's responsibility to prepare plans and implement necessary actions for future disease outbreaks. Residential buildings are crucial for the health of the population, as they determine social well-being. Homes had critical importance during lockdown periods during which

people were required to stay home for infection spread prevention. The nature of this home quarantine experience differed significantly from person to person. This invokes a substantial rethinking of housing to prepare humanity for future possible disease outbreaks.

The present paper addresses a critical question to the community of building sustainability research: "What can we learn from the recent pandemic to modify the building suitability criteria and assessment methods that would promote better sustainable living conditions during such difficult periods affecting entire populations?" The answers to this question will lead to significant changes to the existing methods. We specifically expect that existing building sustainability rating methods that mainly favor "environmental impact" and "energy performance" of buildings will receive a significant shift towards emphasizing "social and health" aspects. It is finally encouraging to see the opportunities that the disruption brings, and the improvements that would be implemented may be financially supported by expected COVID-19 stimulus financing for the building industry as well as existing/upcoming green stimulus packages.

COVID-19 pandemic and lockdown measures have revealed the deficiencies in existing residential buildings in terms of health and safety risks, excess consumption of environmental resources, and lack of personal comfort. The following changes are expected to improve health and safety in houses: widened use of touchless and automotive technologies, selection of finishing materials with regards to viral survivability, and development of green spaces. As a response to environmental needs, sustainable technologies mainly and particularly need to address the issue of improving the increased consumption of energy and water. For comfort enhancement, residential houses need to improve communication technologies to use remote services better and use automotive technologies to regulate better comfort parameters: air quality, light, temperature, humidity, and so on.

Future scenarios involving upcoming pandemics cannot be precise, as the nature of the coronavirus, as well as its spreading behavior, are still being researched. Nevertheless, humanity should be ready for possible repeating outbreaks of COVID as well as other pandemics. Therefore, it is crucial to understand the requirements under pandemic scenarios and design resilient solutions. Future work can proceed in (1) the development of novel building codes and green certificates for the post-pandemic residential buildings and/or (2) the modification of existing codes and certificates considering particular pandemic needs.

References

1. Nghiem, L.D.; Morgan, B.; Donner, E.; Short, M.D. The COVID-19 Pandemic: Considerations for the waste and wastewater services sector. Case Stud. Chem. Environ. Eng. 2020, 1, 100006, doi:10.1016/j.cscee.2020.100006.
2. Hui, D.S.; Azhar, E.I.; Madani, T.A.; Ntoumi, F.; Kock, R.; Dar, O.; Ippolito, G.; Mchugh, T.D.; Memish, Z.A.; Drosten, C.; et al. The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health—The latest 2019 novel coronavirus outbreak in Wuhan, China. Int. J. Infect. Dis. 2020, 91, 264–266, doi:10.1016/j.ijid.2020.01.009.
3. Morris, A. Coronavirus Outbreak Is Part of Worldwide Increase in Disease Spread. Available online: https://www.azcentral.com/story/news/local/arizona-health/2020/03/30/coronavirus-covid-19-outbreak-part-worldwide-increase-disease-spread/5048560002/ (accessed on 9 September 2020).
4. Eykelbosh, A. COVID-19 Precautions for Multi-Unit Residential Buildings; National Collaborating Centre for Environmental Health: Winnipeg, MB, Canada, 2020.
5. Dietz, L.; Horve, P.F.; Coil, D.A.; Fretz, M.; Eisen, J.A.; Van Den Wymelenberg, K. 2019 Novel Coronavirus (COVID-19) Pandemic: Built Environment Considerations to Reduce Transmission. mSystems 2020, doi:10.1128/mSystems.00245-20.
6. Harapan, H.; Itoh, N.; Yufika, A.; Winardi, W.; Keam, S.; Te, H.; Megawati, D.; Hayati, Z.; Wagner, A.L.; Mudatsir, M. Coronavirus disease 2019 (COVID-19): A literature review. J. Infect. Public Health 2020, 13, 667–673, doi:10.1016/j.jiph.2020.03.019.
7. Megahed, N.A.; Ghoneim, E.M. Antivirus-built environment: Lessons learned from Covid-19 Pandemic. Sustain. Cities Soc. 2020, 61, 102350, doi:10.1016/j.scs.2020.102350.
8. Nicola, M.; Alsafi, Z.; Sohrabi, C.; Kerwan, A.; Al-Jabir, A.; Iosifidis, C.; Agha, M.; Agha, R. The socio-economic implications of the coronavirus pandemic (COVID-19): A review. Int. J. Surg. 2020, 78, 185–193, doi:10.1016/j.ijsu.2020.04.018.
9. Filho, W.L.; Brandli, L.L.; Salvia, A.L.; Rayman-Bacchus, L.; Platje, J. COVID-19 and the UN sustainable development goals: Threat to solidarity or an opportunity? Sustainability 2020, 12, 5343, doi:10.3390/su12135343.
10. Aitharaju, R. Digital Transformation and Sustainability: A Post-COVID Impact Analysis of Global Businesses. In Proceedings of the Global Business Trends In View of Lock Down and Role Of Digital Transformation for Sustainability.

2020, 35–38.

11. Blay-Palmer, A.; Carey, R.; Valette, E.; Sanderson, M.R. Post COVID 19 and food pathways to sustainable transformation. Agric. Human Values 2020, 37, 517–519, doi:10.1007/s10460-020-10051-7.
12. Tran, T.; Hoang, A.D.; Nguyen, Y.C.; Nguyen, L.C.; Ta, N.T.; Pham, Q.H.; Pham, C.X.; Le, Q.A.; Dinh, V.H.; Nguyen, T.T. Toward sustainable learning during school suspension: Socioeconomic, occupational aspirations, and learning behavior of vietnamese students during COVID-19. Sustainability 2020, 12, doi:10.3390/su12104195.
13. D'alessandro, D.; Gola, M.; Appolloni, L.; Dettori, M.; Fara, G.M.; Rebecchi, A.; Settimo, G.; Capolongo, S. COVID-19 and living space challenge. Well-being and public health recommendations for a healthy, safe, and sustainable housing. Acta Biomed. 2020, 91, 61–75, doi:10.23750/abm.v91i9-S.10115.
14. UN News. Coronavirus Update: COVID-19 Likely to Cost Economy $1 Trillion during 2020, Says UN Trade Agency. Available online: https://news.un.org/en/story/2020/03/1059011 (accessed on 13 September 2020).
15. Gracy, B. Digital Transformation: 4 Ways to Plan for the Post-Pandemic Normal. Available online: https://enterprisersproject.com/article/2020/4/digital-transformation-how-plan-post-pandemic (accessed on 13 September 2020).
16. Makhno, S. Life after Coronavirus: How Will the Pandemic Affect Our Homes? Available online: https://www.dezeen.com/2020/03/25/life-after-coronavirus-impact-homes-design-architecture/ (accessed on 13 September 2020).
17. Wainwright, O. Smart Lifts, Lonely Workers, No Towers or Tourists: Architecture after Coronavirus. Available online: https://www.theguardian.com/artanddesign/2020/apr/13/smart-lifts-lonely-workers-no-towers-architecture-after-covid-19-coronavirus (accessed on 13 September 2020).
18. Dreessen, T. How COVID-19 Will Change the Design of Our Cities. Available online: https://www.obj.ca/article/sponsored-architects-dca-how-covid-19-will-change-design-our-cities (on accessed Sep).
19. Zhou, H.; He, S.; Cai, Y.; Wang, M.; Su, S. Social inequalities in neighborhood visual walkability: Using street view imagery and deep learning technologies to facilitate healthy city planning. Sustain. Cities Soc. 2019, 50, 101605, doi:10.1016/j.scs.2019.101605.
20. Molla, R. This Is the End of the Office as We Know It. Available online: https://www.vox.com/recode/2020/4/14/21211789/coronavirus-office-space-work-from-home-design-architecture-real-estate (accessed on 13 September 2020).
21. Marr, B. How the COVID-19 Pandemic Is Fast-Tracking Digital Transformation in Companies. Available online: https://www.forbes.com/sites/bernardmarr/2020/03/17/how-the-covid-19-pandemic-is-fast-tracking-digital-transformation-in-companies/#54281a93a8ee (accessed on 13 September 2020).
22. Smith, R.; Quale, J. Offsite Architecture: Constructing the Future; Taylor & Francis: Abingdon, UK, 2017.
23. Hatcher, J. Modular Buildings in the Time of Covid-19. Available online: https://smartbuildingsmagazine.com/features/modular-buildings-in-the-time-of-covid-19 (accessed on 15 September 2020).
24. Lubell, S. Commentary: Past Pandemics Changed the Design of Cities. Six Ways COVID-19 Could Do the Same. Available online: https://www.latimes.com/entertainment-arts/story/2020-04-22/coronavirus-pandemics-architecture-urban-design (accessed on 15 September 2020).
25. Constable, H. The New Coronavirus Has Spread Rapidly in Cities around the Globe. How Might the Virus Make Us Think Differently about Urban Design in the Future? Available online: https://www.bbc.com/future/article/20200424-how-do-you-build-a-city-for-a-pandemic (accessed on 7 September 2020).
26. Kashdan, R. Six Ways Urban Spaces May Change Because of Coronavirus. Available online: https://www.bostonmagazine.com/property/2020/04/30/urban-spaces-coronavirus/ (accessed on 15 September 2020).
27. Lin, F.; Howell-Jones, M. Smart Construction Could Transform Home-Building after COVID-19. Available online: https://www.weforum.org/agenda/2020/08/here-s-how-smart-construction-could-transform-home-building-after-covid-19/ (accessed on 13 September 2020).
28. Hoffer, A. How the Coronavirus Is Affecting Home Construction. Available online: https://www.washingtonpost.com/business/2020/06/11/business-our-new-normal-pandemics-effect-home-construction-market/?arc404=true (accessed on 13 September 2020).
29. Ali, H.M.; Dom, M.M.; Sahrum, M.S. Self-Sufficient Community through the Concepts of Collective Living and Universal Housing. Procedia Soc. Behav. Sci. 2012, 68, 615–627, doi:10.1016/j.sbspro.2012.12.253.

30. Priday, C. Architecture after Coronavirus Available online: https://exepose.com/2020/05/05/architecture-after-coronavirus/ (accessed on 7 September 2020).
31. Capolongo, S.; Rebecchi, A.; Buffoli, M.; Appolloni, L.; Signorelli, C.; Fara, G.M.; D'Alessandro, D. COVID-19 and cities: From urban health strategies to the pandemic challenge. A decalogue of public health opportunities. Acta Biomed. 2020, 91, 13–22, doi:10.23750/abm.v91i2.9515.
32. Harrouk, C. Architecture Post COVID-19: The Profession, the Firms, and the Individuals. Available online: https://www.archdaily.com/939534/architecture-post-covid-19-the-profession-the-firms-and-the-individuals (accessed on 13 September 2020).
33. Wintle, T. COVID-19 and the City: The Future of Pandemic-Proofed Buildings. Available online: https://newseu.cgtn.com/news/2020-07-12/COVID-19-and-the-city-The-future-of-pandemic-proofed-buildings-RCqRHMSn72/index.html (accessed on 13 September 2020).
34. Dettori, M.; Altea, L.; Fracasso, D.; Trogu, F.; Azara, A.; Piana, A.; Arghittu, A.; Saderi, L.; Sotgiu, G.; Castiglia, P. Housing Demand in Urban Areas and Sanitary Requirements of Dwellings in Italy. J. Environ. Public Health 2020, 2020, 7642658, doi:10.1155/2020/7642658.
35. Lippe-McGrow, J. The Future of Design after COVID-19. Available online: https://www.departures.com/lifestyle/architecture/architects-predict-future-of-design (accessed on 13 September 2020).
36. Zambrano-Monserrate, M.A.; Ruano, M.A.; Sanchez-Alcalde, L. Indirect effects of COVID-19 on the environment. Sci. Total Environ. 2020, 728, doi:10.1016/j.scitotenv.2020.138813.
37. Bahadursingh, N. 8 Ways COVID-19 Will Change Architecture. Available online: https://architizer.com/blog/inspiration/industry/covid19-city-design/ (accessed on 14 September 2020).
38. Grant, M.J.; Booth, A. A typology of reviews: An analysis of 14 review types and associated methodologies. Health Inf. Libr. J. 2009, 26, 91–108, doi:10.1111/j.1471-1842.2009.00848.x.
39. Committee for the Coordination of Statistical Activities . How COVID-19 Is Changing the World: A Statistical Perspective; United Nations Conference on Trade and Development, 2020.
40. Moreno, C.; Wykes, T.; Galderisi, S.; Nordentoft, M.; Crossley, N.; Jones, N.; Cannon, M.; Correll, C.U.; Byrne, L.; Carr, S.; et al. How mental health care should change as a consequence of the COVID-19 Pandemic. Lancet Psychiatry 2020, 7, 813–824, doi:10.1016/S2215-0366(20)30307-2.
41. UNFPA Kazakhstan. UNFPA Kazakhstan|People in Kazakhstan Report More Cases of Domestic Violence during Quarantine. Available online: https://kazakhstan.unfpa.org/en/news/people-kazakhstan-report-more-cases-domestic-violence-during-quarantine (accessed on 6 September 2020).
42. Akisheva, B.A. Women Face-To-Face with Domestic Abuse during COVID-19; Central Asia Program, 2020.
43. Pannier, B.; Tahir, M. Majlis Podcast: With Coronavirus, Domestic Violence in Central Asia Has Gotten Much Worse. Available online: https://www.rferl.org/a/majlis-podcast-with-coronavirus-domestic-violence-in-central-asia-has-gotten-much-worse/30707018.html (accessed on 6 September 2020).
44. Taub, A. How Domestic Abuse Has Risen Worldwide since Coronavirus—The New York Times. Available online: https://www.nytimes.com/2020/04/06/world/coronavirus-domestic-violence.html (accessed on 6 September 2020).
45. Clair, A. Homes, Health, and COVID-19: How Poor Housing Adds to the Hardship of the Coronavirus Crisis—Social Market Foundation. Available online: https://www.smf.co.uk/commentary_podcasts/homes-health-and-covid-19-how-poor-housing-adds-to-the-hardship-of-the-coronavirus-crisis/ (accessed on 9 September 2020).
46. BBC. Coronavirus: Domestic Electricity Use up during Day as Nation Works from Home—BBC News. Available online: https://www.bbc.com/news/technology-52331534 (accessed on 7 September 2020).
47. Abergel, T.; Delmastro, C.; Kevin, L. Buildings—The Covid-19 Crisis and Clean Energy Progress; International Energy Agency, 2020.
48. Freire-González, J.; Font Vivanco, D. Pandemics and the Environmental Rebound Effect: Reflections from COVID-19. Environ. Resour. Econ. 2020, 1–4, doi:10.1007/s10640-020-00448-7.
49. Edomah, N.; Ndulue, G. Energy transition in a lockdown: An analysis of the impact of COVID-19 on changes in electricity demand in Lagos Nigeria. Glob. Transit. 2020, 2, 127–137, doi:10.1016/j.glt.2020.07.002.
50. Eroğlu, H. Effects of Covid-19 outbreak on environment and renewable energy sector. Environ. Dev. Sustain. 2020, doi:10.1007/s10668-020-00837-4.
51. Pinheiro, M.D.; Luís, N.C. COVID-19 could leverage a sustainable built environment. Sustainability 2020, 12, doi:10.3390/su12145863.

52. Kalbusch, A.; Henning, E.; Brikalski, M.P.; de Luca, F.V.; Konrath, A.C. Impact of coronavirus (COVID-19) spread-prevention actions on urban water consumption. Resour. Conserv. Recycl. 2020, 163, 105098, doi:10.1016/j.resconrec.2020.105098.

53. Mukherjee, A.; Babu, S.S.; Ghosh, S. Thinking about water and air to attain Sustainable Development Goals during times of COVID-19 Pandemic. J. Earth Syst. Sci. 2020, 129, doi:10.1007/s12040-020-01475-0.

54. Wang, J.; Feng, H.; Zhang, S.; Ni, Z.; Ni, L.; Chen, Y.; Zhuo, L.; Zhong, Z.; Qu, T. SARS-CoV-2 RNA detection of hospital isolation wards hygiene monitoring during the Coronavirus Disease 2019 outbreak in a Chinese hospital. Int. J. Infect. Dis. 2020, 94, 103–106, doi:10.1016/j.ijid.2020.04.024.

55. Charara, S. Our Terrible Housing Stock Is Making Lockdown Life Even Worse|WIRED UK. Available online: https://www.wired.co.uk/article/coronavirus-architecture-isolation-home-design (accessed on 10 September 2020).

56. WHO. Water, Sanitation, Hygiene, and Waste Management for SARS-CoV-2, the Virus That Causes COVID-19; WHO: Geneva, Switzerland, 2020.

57. Inform.kz. 42500: Более 2,6 Млн Граждан Подали Заявки на Получение Выплаты. Available online: https://www.inform.kz/ru/42500-bolee-2-6-mln-grazhdan-podali-zayavki-na-poluchenie-vyplaty_a3690014 (accessed on 10 September 2020).

58. Tikhonova, Y. Коммунальная Помощь. Available online: https://time.kz/articles/territory/2020/05/06/kommunalnaya-pomoshh (accessed on 10 September 2020).

59. Mediazona.ca. Общество Закрытых Подъездов. Записки Алматинца, Попавшего под Принудительный Карантин. Available online: https://mediazona.ca/article/2020/04/06/covid-19-diary (accessed on 5 September 2020).

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

61. United NationsGeneral Assembly: 2005 World Summit Outcome; 2005.

62. Ardda, N.; Mateus, R.; Bragança, L. Methodology to identify and prioritise the social aspects to be considered in the design of more sustainable residential buildings-Application to a developing country. Buildings 2018, 8, doi:10.3390/buildings8100130.

63. Awadh, O. Sustainability and green building rating systems: LEED, BREEAM, GSAS and Estidama critical analysis. J. Build. Eng. 2017, 11, 25–29, doi:10.1016/j.jobe.2017.03.010.

64. Marshall, W. Can COVID-19 (Coronavirus) Spread through Food, Water, Surfaces and Pets?—Mayo Clinic. Available online: https://www.mayoclinic.org/diseases-conditions/coronavirus/expert-answers/can-coronavirus-spread-food-water/faq-20485479 (accessed on 16 September 2020).

65. 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.; et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N. Engl. J. Med. 2020, 382, 1564–1567.

66. Stambol Touchless Technology in the Wake of COVID-19. Available online: https://www.stambol.com/2020/05/11/touchless-technology-in-the-wake-of-covid-19/ (accessed on 19 September 2020).

67. Spolidoro, B. Healthy Buildings: How Architecture Can Defend Us from COVID-19. Available online: https://www.workdesign.com/2020/05/healthy-buildings-how-architecture-can-defend-us-from-covid-19/ (accessed on 19 September 2020).

68. Brownell, B. Materials and Coatings That Reduce Surface Transmission of Bacteria and Viruses. Available online: https://www.architectmagazine.com/technology/materials-and-coatings-that-reduce-surface-transmission-of-bacteria-and-viruses_o (accessed on 19 September 2020).

69. Hounsell, D. Can Antimicrobials Added to Products Prevent COVID-19? Available online: https://www.facilitiesnet.com/facilitiesmanagement/tip/Can-Antimicrobials-Added-to-Products-Prevent-COVID-19--46366 (accessed on 19 September 2020).

70. Ehrlich, B. Antimicrobials in Building Products: The COVID-19 Edition. Available online: https://www.buildinggreen.com/product-review/antimicrobials-building-products-covid-19-edition (accessed on 19 September 2020).

71. Healthy Building Network Do Antimicrobial Building Products Protect against COVID-19? 2020.

72. Walsh, B.; Stephens, B.; Dickinson, M.; Richter, M.; Stamm, R.; McGrath, T. Understanding Antimicrobial Ingredients in Building Materials. Perkins Will 2020, doi:10.1002/3527600418/homepage/.

73. County Stone. Everything you need to know about Lapitec. Available online: https://www.countystonegranite.co.uk/blog/inspiration/everything-need-know-lapitec/ (accessed on 24 September 2020).
74. KRION. What Is KrionTM? A Material for Unlimited Surfaces. Available online: https://www.krion.com/en/what-is-krion (accessed on 24 September 2020).
75. Ruijsbroek, A.; Droomers, M.; Kruize, H.; Van Kempen, E.; Gidlow, C.J.; Hurst, G.; Andrusaityte, S.; Nieuwenhuijsen, M.J.; Maas, J.; Hardyns, W.; et al. Does the health impact of exposure to neighbourhood green space differ between population groups? An explorative study in four European cities. Int. J. Environ. Res. Public Health 2017, 14, doi:10.3390/ijerph14060618.
76. van den Berg, A.E.; Maas, J.; Verheij, R.A.; Groenewegen, P.P. Green space as a buffer between stressful life events and health. Soc. Sci. Med. 2010, 70, 1203–1210, doi:10.1016/j.socscimed.2010.01.002.
77. Beyer, K.M.M.; Kaltenbach, A.; Szabo, A.; Bogar, S.; Javier Nieto, F.; Malecki, K.M. Exposure to neighborhood green space and mental health: Evidence from the survey of the health of wisconsin. Int. J. Environ. Res. Public Health 2014, 11, 3453–3472, doi:10.3390/ijerph110303453.
78. Maas, J.; Verheij, R.A.; De Vries, S.; Spreeuwenberg, P.; Schellevis, F.G.; Groenewegen, P.P. Morbidity is related to a green living environment. J. Epidemiol. Community Health 2009, 63, 967–973, doi:10.1136/jech.2008.079038.
79. Cohen-Cline, H.; Turkheimer, E.; Duncan, G.E. Access to green space, physical activity and mental health: A twin study. J. Epidemiol. Community Health 2015, 69, 523–529, doi:10.1136/jech-2014-204667.
80. Soga, M.; Gaston, K.J.; Yamaura, Y. Gardening is beneficial for health: A meta-analysis. Prev. Med. Rep. 2017, 5, 92–99, doi:10.1016/j.pmedr.2016.11.007.
81. Settimo, G. Residential indoor air quality: Significant parameters in light of the new trends. Ig. Sanita Pubbl. 2012, 68, 136–138.
82. Settimo, G.; Bertinato, L.; Bonadonna, L.; D'Ancona, P.; Santarsiero, A.; Soggiu, M.E. Indicazioni ad Interim per la Prevenzione e Gestione degli Ambienti Indoor in Relazione alla Trasmissione Dell'infezione da Virus SARS-CoV-2; Istituto Superiore di Sanità: Rome, Italy, 2020.
83. Signorelli, C.; Capolongo, S.; Buffoli, M.; Capasso, L.; Faggioli, A.; Moscato, U.; Oberti, I.; Petronio, M.G.; D'Alessandro, D. Italian Society of Hygiene (SItI) recommendations for a healthy, safe and sustainable housing. Epidemiol. Prev. 2016, 40, 265–270, doi:10.19191/EP16.3-4.P265.094.
84. Constellation Energy-Saving Strategies for Smart Homes. Available online: https://blog.constellation.com/2019/01/22/smart-home-energy-saving-strategies/ (accessed on 23 September 2020).
85. Ampower. Top 7 New Energy Saving Technology for Your Home. Available online: https://www.ampoweruk.com/2019/07/16/top-7-new-energy-saving-technology-for-your-home (accessed on 23 September 2020).
86. Cyranoski, D.; Abbott, A. Apartment complex holds clues to pandemic potential of SARS. Nature 2003, 423, 3–4, doi:10.1038/423003a.
87. Lodder, W.; de Roda Husman, A.M. SARS-CoV-2 in wastewater: Potential health risk, but also data source. Lancet Gastroenterol. Hepatol. 2020, 5, 533–534.
88. Marlin, C. How COVID-19 Will Change the Way We Design Our Homes. Available online: https://www.weforum.org/agenda/2020/08/how-covid-19-will-change-what-we-call-home-ddfe95b686/ (accessed on 17 September 2020).
89. Jameson, M. 15 Ways Homes Will Change Post-COVID-19. Available online: https://www.mercurynews.com/2020/06/04/15-ways-homes-will-change-post-covid-19/ (accessed on 17 September 2020).
90. D'Alessandro, D.; Raffo, M. Adapting the answers to new problems of living in a changing society. Ann. Ig. Med. Prev. Comunità 2011, 23, 267–274.
91. Capasso, L.; Gaeta, M.; Appolloni, L.; D'Alessandro, D. Health inequalities and inadequate housing: The case of exceptions to hygienic requirements for dwellings in Italy. Ann. Ig. 2017, 29, 323–331, doi:10.7416/ai.2017.2159.
92. Stephens, N. 6 Biggest Challenges of Working from Home. Available online: https://www.vault.com/blogs/workplace-issues/challenges-of-working-from-home (accessed on 22 September 2020).
93. Parungao, A. The Future of Remote Work after COVID-19: 3 Common Predictions. Available online: https://www.ekoapp.com/blog/the-future-of-remote-work-after-covid-19-3-common-predictions (accessed on 22 September 2020).

94. Boland, B.; De Smet, A.; Palter, R.; Sanghvi, A. Reimagining the Office and Work Life after COVID-19. Available online: https://www.mckinsey.com/business-functions/organization/our-insights/reimagining-the-office-and-work-life-after-covid-19# (accessed on 22 September 2020).
95. Hipwood, T. The End of Open-Plan Living? How Covid-19 Is Changing Our Homes. Available online: https://www.fastcompany.com/90515499/the-end-of-open-plan-living-how-covid-19-is-changing-our-homes (accessed on 24 September 2020).
96. Bahadursingh, N. 6 Ways COVID-19 Will Change Home Design. Available online: https://architizer.com/blog/inspiration/industry/covid-19-home-design/ (accessed on 24 September 2020).