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Review

COVID-19 and City Space: Impact and Perspectives

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Abstract: The pandemic of the COVID-19 disease has radically changed human lifestyle and the usage of living space, especially in cities. With the prolongation of the crisis, the effects of COVID-19 on urban spaces are becoming more noticeable, but the definite changes that can inform approaches to future development, planning, and use of urban space have not yet been determined, as evidenced by the research carried out in this study. The research revealed that there exists the consensus in terms of several new guidelines whose application in design can simultaneously increase the resilience of urban environment to future pandemics and improve the overall quality of city life. These presented guidelines show that we may expect in the future a greater integration of nature-based solutions at various scales of the city, i.e., better ventilated, and naturally lit, more spacious, mixed-use, and flexible buildings surrounded by enlarged, multiplied, and multifunctional open spaces that safely receive the users who are carrying out those activities that were moved from the inner to the outer space.

Keywords: pandemic impact; city space; post-COVID-19 future; urban and architectural design guidelines

Citation: Lekić Glavan, O.; Nikolić, N.; Folić, B.; Vitošević, B.; Mitrović, A.; Kosanović, S. COVID-19 and City Space: Impact and Perspectives. *Sustainability* **2022**, *14*, 1885. https://doi.org/10.3390/su14031885

Academic Editor: Agnieszka Bieda

Received: 29 December 2021
Accepted: 31 January 2022
Published: 7 February 2022

1. Introduction

Mankind has been facing epidemics of various infectious diseases for centuries [1–3]. However, the data on impact of these crises on settlement areas are scarce [4–6]. Next to the critical impacts on human life in all parts of the planet, the outbreak of the COVID-19 contagious disease at the beginning of 2020 created an opportunity to review urban vulnerability and resilience [7], and to define and apply reinforcement measures [3], globally, regionally, and locally.

The pandemic represented a surprise, and the mode of transmission and the nature of the virus were initially insufficiently known, hence the first measures to combat contagion in human settlements, especially in cities, referred to restrictions in the use of space. Epidemiological problems have thus become urban problems [6]. With 'stay-at-home' orders and recommendations, the ways of carrying out the city's activities such as education, work, shopping, or leisure, changed. Mobility within the city space [8–11] as well as the public transportation were significantly reduced. Various lockdown-related measures, such as curfew, cordon sanitaire, or quarantine, were established at the scale of a whole city, a neighborhood, or a single building, depending on epidemiological situation. The measure of physical distance between the individuals was introduced. Initially, the safe distance was set at 2 m; later on, it was reduced to 1.5 m, and according to the latest recommendations, it is 1 m [12]. Joint activities, gatherings, and manifestations were cancelled or postponed. Hygiene measures in public spaces were substantially tightened. Face masks became the leading symbol of the pandemic, and pharmacies and grocery stores the most popular places to visit.

COVID-19 restrictions and measures, however, have not been applied to the same extent and at the same time in different countries, e.g., at the time when the lockdown of Wuhan and other cities in Hubei province in China terminated, in early spring of 2020 [13], the closure of the cities in the Western countries just began. Therefore, for a comprehensive study of the impact of the COVID-19 pandemic on urban space it is necessary to conduct a broad review, as performed in this study. The objectives of the study are to register the pandemic's main impacts on a city through analysis of worldwide space-related measures for disease control, to examine published works and consider authors' views on spatial consequences of COVID-19 and their permanence, and to acknowledge and describe the newly emerged guidelines for spatial design that will likely be applied in post-COVID-19 cities. The contribution of this review to the subject field of research is reflected in the methodological approach to the identification of design guidelines for post-COVID-19 cities, i.e., in their logical reasoning based on both the manifested and the possible changes, challenges, and needs of the city in health-related crisis situations.

2. COVID-19 and Life in the City

The lockdowns caused by the COVID-19 pandemic made profound changes to the usual city life. Lockdown measures were applied either to the whole city, or, more rarely, at the neighborhood level. Examples of the second case include the closure of a densely populated district in Hong Kong [14], two urban districts in Luanda, Angola [15], and several neighborhoods in Beijing [16,17].

Defined groups of citizens (retirees, people with pets, parents with children) were allowed to leave their homes only at certain time intervals and/or at certain distances. In Serbia, for example, people over 65 were at the beginning of pandemic allowed to exit their homes only to buy groceries, once per week, in the period from 4 to 7 a.m. [18]. During the second national lockdown and related 24-h movement restrictions in Greece, the inhabitants were allowed to leave their homes only in special cases, and by informing the authorities via short message service [19]. In Australia, just one person from the household was allowed to leave a residence within the radius of 5 km, once a day, at the time when curfew was not in force [20]. Mobility restrictions determined by time or distance constrains were oftentimes related to citizens' movement within their own neighborhoods [21–23]. Contrary, in countries such as Sweden or Brazil, lockdown measures were not compulsory [24,25]; instead, the mitigation of the virus spread in these territories was maintained on the basis of recommendations. In countries where mobility restrictions were common, people expressed their dissatisfaction by organizing protests at home balconies or on the streets [26–28]. Furthermore, the COVID-19 pandemic and related health threats imposed numerous restrictions to the use of common open space. Many public gatherings and open space events were cancelled or postponed, or the number of attendees significantly reduced [29], all to the users of a single building. In Tel Aviv, for example, open performances organized on the rooftops of residential buildings were accessible only to the occupants of those buildings [30].

Restrictions were also applied to green/natural urban areas, beaches, parks, and urban forests, from limiting the number of visitors to their full closure. The last measure, in particular, caused a lot of controversy and raised opposition, having regarded that green space provides health safeguarding and the much-needed stress relief [31–36]. There also exist those examples where roads and open parking lots were informally transformed into areas for pedestrians and bikers, as a substitute to closed parks. Such spontaneous open space adaptation in some cases increased the risk of disease transmission due to unregulated overcrowding. As a part of locally organized actions, city streets and parking lots have since the beginning of pandemic been used for installing COVID-19-specific elements and enabling safe children play, socialization, recreation, exercising, shopping, groceries delivery, outdoor dining, education-, cultural- and religious-related activities, and even the voting [37].

Open space restrictions were oftentimes related to specific amenities, such as the squares, open gyms, and public bathrooms, or to specific urban elements such as play

equipment, bike racks, seating, or rubbish bins. In open markets, plastic protective shields were installed to mutually protect sellers and buyers. Visits to cemeteries were reduced; the number of people at funerals was limited, or there was a temporary ban to funeral ceremonies [38,39]. Christmas markets were mostly closed in the first year of the pandemic; in winter 2021, some Christmas markets were reopened, in accordance with the latest safety and health measures [40], and similar was the case with children's playgrounds [41].

Common neighborhood places intended for socialization, sports, recreation, or small business were either closed or open to a reduced number of clients, within reduced working hours. In some cases, alternative business models were introduced or strengthened; for example, cafés and restaurants placed a new accent on home delivery. Applied temporal closures of third places impacted casual social ties, although the perceived effects on psychological well-being are minimal [42]. On the other hand, neighborhood communities commonly self-organized to help their vulnerable members, resulting in reinforced interpersonal relationships. With the reopening of service facilities, the expansion of seating areas into laneways and sidewalks occurred in many cities. Wearing a mask, keeping the distance, and possessing a vaccination certificate or a negative test for COVID-19 are gradually becoming mandatory prerequisites for visiting the third places, and the previously extended seating areas are back to the original spatial frames, accordingly.

In terms of closed space, ventilation, daylight, occupancy rate, materialization, and hygiene were recognized as critical parameters for disease transmission. To prevent the spread of the virus, one of the first mandatory measures implemented nationally, regionally, or locally, therefore, was the closure of public buildings such as schools, libraries, offices, indoor markets, shopping malls, sport halls, museums, movies and theatres, churches, and others. Residential buildings were subjected to locking down.

Due to negative effects, the measure of mandatory locking down the occupants of multi-residential buildings has been debated in literature extensively, e.g., [43,44]. Balconies, terraces, private courtyards, and gardens became critical spatial residential elements that provide the only connection with the outdoors during the lockdown period. Oppositely, the voluntary stay at home measure was recognized as a "voluntary quarantine and has been transformed into an important moral statement that has been highly recommended by media, the public health officials as well as the government authorities" [45] (p. 2). Hence, a residential closed space in the time of pandemic became an isolation healthcare unit for those individuals who might be infected, or were infected but display a mild form of the disease. The new health-related function further on impacted the conventional manner of using the residential space when both the healthy and the infected, or the potentially infected persons, resided in one same unit, demanding for its temporary division and readjustment. Moreover, the living space must satisfy many other imposed requirements (e.g., work from home, space for entertainment, space for physical activity, space for socializing, etc.), and this leads to the problem of insufficient surface area. Accordingly, the reorganization of the interior space of homes, especially during the lock-down, became frequent. This is particularly noticeable in families with children [3], where the indoor living space provides a substitution to a park, playground, or sports ground.

Where high-occupancy public buildings remained opened, or were reopened following a period of peak virus transmission, the upper limits in occupancy rates (the number of occupants per m^2) were established, and the protective equipment introduced, e.g., transparent panels dividing employees from customers in banks, post offices, or grocery stores. Furthermore, the introduction of COVID-19-related measures raised the changes in movement though the existing closed space, e.g., within airports, public transport stations, or healthcare buildings, followed by the introduction of new functional points such as sanitizing stations, testing stations, temperature check stations, isolation rooms, disinfection tunnels, vaccination points, and other.

There were several time periods since the beginning of pandemic where the number of infected patients in need of hospitalization exceeded the available capacities of local, regional, and national health systems. For that reason, public buildings such as sports and

fair halls, e.g., [46], were temporarily transformed into emergency COVID-19 hospitals. Likewise, many hotels, motels, and spa resorts around the world were functionally transformed into quarantine centers or temporary accommodation for homeless and other vulnerable individuals and families [47,48].

Next to the adaptive measures applied to existing non-health buildings, emergency construction/installation of new COVID-19-specific facilities, such as separate quarantine centers [49–51], COVID-19 hospitals [52–54], or public points for testing and vaccination, were also established. The common features of these COVID-19-specific structures included quick erection or installation, use of prefabricated and modular construction systems, and oftentimes, the deprivation of the quality of architectural form. In sporadic cases, even trains [55] and ships [56,57] were used as COVID-19-specific elements.

To improve hygiene, temporary hand-sanitizer stations and disinfectant supply stations were installed throughout the cities and their belonging neighborhoods. Disinfection tunnels/gates/cabinets/booths, based on the principle of spraying the disinfectant, chemical aspersion, or the irradiation with ultraviolet rays, have also started to appear, but their use was put in question due to possible negative health effects [58–60].

Within the open urban space, signs, signalization, and information boards for new ways of using the public amenities and the space during the pandemic were installed.

Restrictions made to urban transportation impacted the functionality of mobility-related open space. The most extreme cases include the self-initiated destruction of the roads or setting up the road barricades in order to cut commuting ties and accordingly the spread of the virus [61,62]. Commonly applied reduction in the capacity of public transportation vehicles as well as the self-initiated crowd avoiding made a twofold impact on city streets: except for the early pandemic period, the number of both the pedestrians and bikers, and the private vehicles [63,64], increased. In line with the policy of promoting the journeys on foot and by bicycle, some cities extended the length of bike paths and widened the pedestrian zones [1,65,66].

On the one hand, introduced restrictions to the use of urban space generated numerous negative social and economic side consequences [67,68]. On the other hand, the overall ecological state of urban environment mainly benefited from such a situation, at least temporarily. Wildlife's performance, air quality, and the quality of surface water and groundwater were bettered, while the urban noise and the heat island effect were reduced [69–74]. The exceptions, however, refer to increased pollution due to disposal of sanitary consumables [71], increased level of ozone [73], waste accumulation, and reduction in recycling [74].

Figure 1 illustrates the scope of changes introduced to city life due to the COVID-19 pandemic, in line with above presented.

Another significant phenomenon, that reoccurred following decades of stagnation, was the growing interest of city dwellers in rural properties and activities, and in rural life in general, e.g., [75,76]. Only in Great Britain, for instance, the number of potential buyers of rural properties increased by 126%; in Liverpool, this increase amounted to 275%, in Edinburgh 205%, and in Birmingham 186%, compared with the previous year [77]. The number of occasional visitors to rural areas increased, too [78]. To prevent the outflow of population from cities to villages, and to control further infection spread, the authorities took various actions on promoting the stay at home, through media recommendations, messages displayed on the roads, by closing cultural and natural sites, etc. Simultaneously, a noticeable increase in sales and demand for larger houses in urban and suburban areas was registered [79]. In some city centers, oppositely, the costs of real estate decreased, e.g., [76].

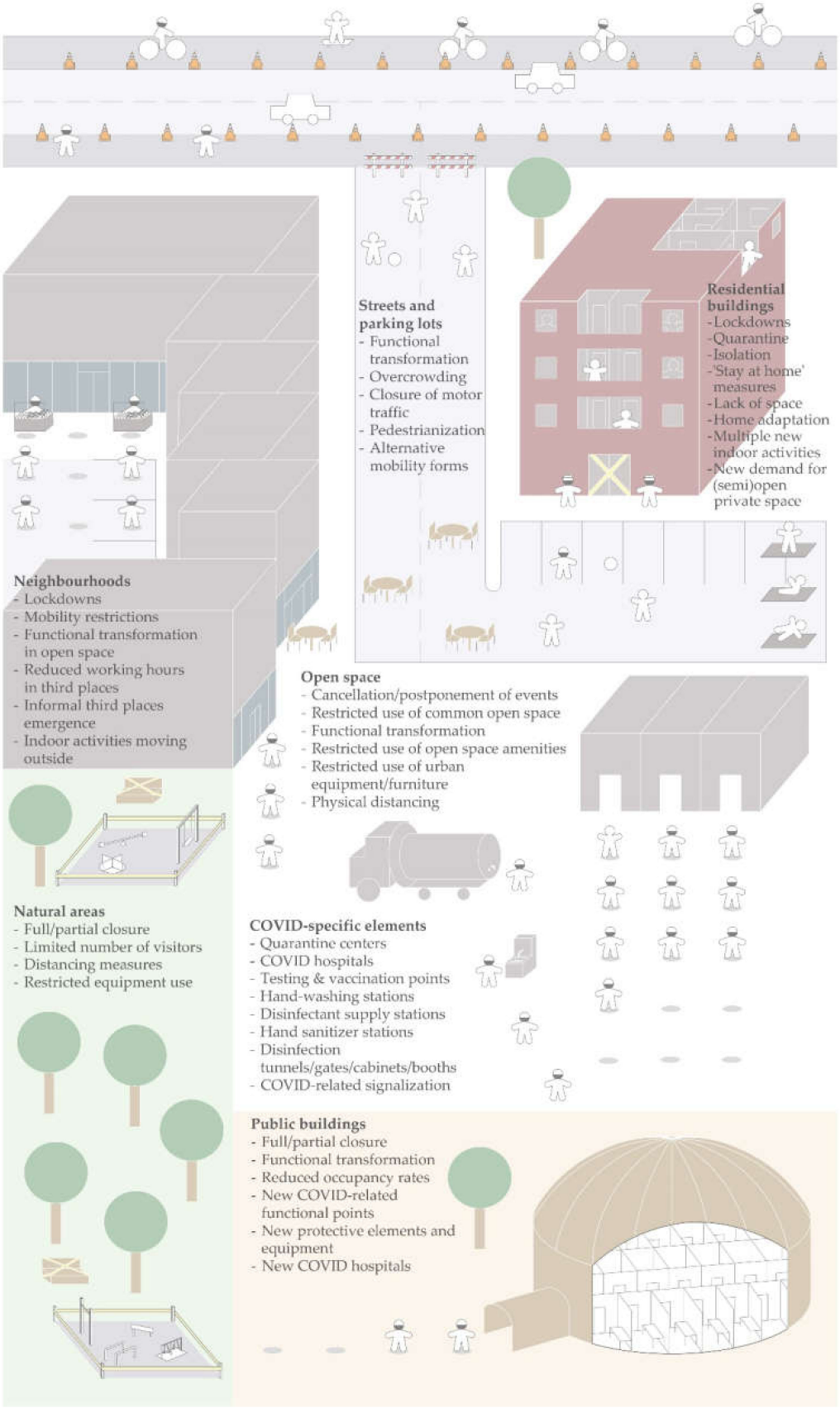

Figure 1. COVID-19 city. The scope of changes applied to different elements of urban environment during COVID-19 pandemic.

The enthusiasm for rural life, and the understanding of it as a way to gain back the personal freedom in the time of restrictions, were enabled by a transition to online activities, from education, to work, to shopping, to culture. It is unclear whether this transition will survive as a permanent change, or whether the patterns of city life will return to their pre-pandemic statuses. History shows that urban dwellers often leave cities in times of epidemics. Nevertheless, cities survive and become more resilient after these crises [80].

3. Reflections on Post-COVID-19 Urban Space

The global society traditionally strives to find ways to overcome emerged crises and challenges, in various spheres of engagement. Numerous examples from the history of architecture and urbanism support this claim: from redrawing the spatial matrices of cities such as Paris and Athens, through the introduction of new housing models and the organization of apartment blocks after the Second World War, to the development and application of the principles of designing buildings and cities with reduced negative environmental impact on the environment in the late 20th century. Among these offered solutions for overcoming current problems, both the moderate, and the radical and futuristic [81] ideas can be found.

The COVID-19 crisis sparked many debates and opened many questions regarding further development, shaping and use of the urban environment. The complexity of raised topics is additionally underpinned by the uncertain ending of the still ongoing pandemic. Namely, the strictest measures (lockdowns and mobility limitations) were mainly applied at the beginning of the pandemic. With the appearance of vaccines, health measures have taken precedence over spatial restrictions. In time, however, the number of new infections started to grow again, even in countries with a high level of immunization, e.g., [82,83]. In late autumn 2021 this resulted in two new sets of spatial restrictions: those concerning unvaccinated persons, e.g., [84], and those concerning the whole population.

The pandemic invited different actors of society to rethink concepts of a sustainable, resilient, and healthy built environment, with each space becoming a possible infection hotspot, and each user of that space potentially infected [6]. The need for self-sufficiency is emphasized [30,65,85].

The crisis also pointed to the weaknesses in the existing sociological structure of the city. Such as in previous epidemics [5], inequalities within the urban social environment affected the response to disease outbreak, and tackling this issue must be seen as a part of integral solutions to mitigate the impact of future health crises [2,7]. For example, the low-income groups, and the individuals who do not own a private vehicle, during the pandemic tended to use public transport modes more often than the high-income groups and the individuals who own private vehicles [86]. Likewise, while the workers from low-income households mainly had to go out and work, the majority of workers from high-income households worked from home [87]. Although in standard conditions the use of public transport has numerous environmental and economic benefits, in times of a health crisis it increases the risk of infection and makes low-income groups more susceptible to infection. In order to solve this specific problem and strengthen the resilience, it is necessary to include socio-economic factors and constraints, and to find a response that will meet travel needs [86] even in pandemic time. In high-income countries such as in Sweden, on the other hand, the variations in public transport used during the COVID-19 crisis were reflected though gender and age [88].

Professional designers, academics, and researchers dealing with the connection between the COVID-19 pandemic and further development, functioning, and shaping of the built environment present a wide range of opinions and conclusions. To some, the pandemic represents a turning point following which the global society will not return to pre-pandemic routines, and this will inevitably generate implications for the built environment. The end of the COVID-19 crisis, according to [1], will mark the beginning of changing values, habits, and homes, as houses will become a preferred option in comparison with the life in flats. According to [89], the change in urban geography in post-COVID-19 can be

reflected in downtowns, suburbs, and small nearby towns of large cities, but, otherwise, the urbanization is unlikely to be changed [89].

Furthermore, authors are bringing different opinions on relation between the density and the spread of an infectious disease. In spite of an initial hypothesis that higher density intensifies virus transmission, the evidence on the association between density and COVID-19 spread is contrasting, and the causal links between these two factors are difficult to prove [4,90–92]. For this reason, some authors have approached the issue of density more comprehensively. For instance [93,94], believe that the problem is not in high density itself, but in availability of contents, primarily health-related, in the territory where that density occurs. In this sense, high-density urban areas may even be more favorable than low-density areas such as peri-urban or suburban zones. Hence, the advocacy of compact urban areas continued during the COVID-19 pandemic [4,90]. Insufficient availability of contents can be the cause of the crowding for which there is a clear consensus in terms of accelerating the transmission of the virus among the urban population. However, in settlements with a sensitive social structure, such as in slums [95], density and crowding go hand in hand. If a post-COVID-19 world turns out to be different from the one we know today [3], believes that it can lead to a series of permanent changes in the use of space, in order to avoid crowds. The key to a successful response, according to [94], lies in the distributive diversity of critical services and amenities [96]; where this condition has been fulfilled, even relatively large urban units have proven to be functional under the influence of coronavirus pandemic. Therefore, another topic of initiated debates refers to the right scale of urban space organization, in relation to its unobtrusive functioning during crises caused by infectious diseases, while the principles of sustainable and resilient communities lead to the conclusion that this might be the neighborhood, e.g., [94,97] opt for a more intimate, adaptive, and manageable scale, not strictly corresponding to a neighborhood unit.

Neighborhood food supply has been singled out as another significant pandemic challenge. The risk of food supply chain interruption grows together with the distance from production to consumption site. Next to that, the places that provide food to a large number of customers arriving from different neighborhoods raise the risk of overcrowding. The lessons learned during the COVID-19 pandemic show that the ideal disposition of food production systems within the sole neighborhoods can reduce these mentioned risks notably. Optimally, the goal is to secure the purchase of groceries from the nearest farmers [65,85], thereby reducing the food miles [98].

Regrading functions, the post-COVID-19 urban development can cause changes in transportation [99–102] and working modes [103], and shopping and education can largely go online [3,89]. Lockdown measures and avoidance of face-to-face contact have already contributed to the increased use of telemedicine compared with the pre-COVID-19 period [104], hence the digitalization can also be expected in other, less personally demanding, city activities. This may further cause a significant shift in physical space once intended for mentioned functions, and make an impact to the urban form where these functions were nested. At the least, in physical terms, the cities can become more centers of culture and entertainment and less centers of work and education, and this would be followed by the change in population structure [89].

Architect Vicente Guallart, the author of Xiong'an, a new "self-sufficient", post-COVID-19 city in China, argues that designing cities and buildings cannot continue as if nothing happened [105]. His solution for the new city, however, represents an already known integration of eco-friendly design principles with the productive urban landscape. Therefore, post-COVID-19 spatial design can actually rely on the reactivation or enhancement of sustainable design concepts, where sustainability (of a defined territory) would refer not only to the environmental but as well the socio-cultural and health-related dimensions.

Acknowledging the advantages of (particularly green) open space during crisis, international designers are proposing various solutions for parks and other common urban areas. Some new solutions for open green space go so far as to integrate social distancing

measures. For instance, the project Parc de la Distance developed by the Studio Precht features a public labyrinth-like garden that combines greenery with individual walking paths for short-term solitude based on the social distancing rules. The garden, originally proposed for a vacant plot in Vienna, is a universally applicable [106] yet radical solution for a virus-free green space. The Rimbin (designed by Martin Binder and Claudio Rimmele) is another exemplary concept for an infection-free playground integrating greenery, playground elements, and social distancing measures [107].

In terms of the post-COVID-19 closed space design, authors consider the increase in the surface and the volume of rooms [3], as well as the development and application of virus-resistant materials and coatings [108–112].

4. Post-COVID-19 Requirements and Guidelines for Urban Space

Temporary measures introduced into the physical framework of the city during the pandemic, as described in Section 2 of this study, indeed yielded positive results in slowing virus transmission, but it is still too early to summarize the final outcomes, and to define the most effective spatial methods, given that the further pandemic course is unknown. In that context, the questions concerning the lastingness of pandemic's impacts on city space, and the degree to which the pandemic will cause spatial transformation [3], are fully justifiable.

On the other hand, by reviewing the research published so far, it is possible to single out several topics related to the impact of pandemic on further development, use, and design of the city space. The consensus in terms of likely (and desirable) changes in urban space that will mitigate the effects of possible future epidemics, and at the same time, improve the quality of urban life in general, is reached in the segments discussed below.

4.1. (Re)Shaping the Open Space

The basic human need for others and for nature has been greatly challenged by the COVID-19 pandemic. Except for the periods of lockdowns and the restricted use of open public space [3], citizens from all over the world have been opting to spend more time outdoors in comparison with the pre-pandemic time [113]. 'Life between buildings' [114] has gained an additional relevance, and the culmination has been reached with increased value of the private open space [30,75–79], providing for "invaluable safety from the epidemic and the mental comfort which is indispensable during isolation" [115]. The pandemic has revived the health- and wellbeing-related benefits of the open space.

The extension of crisis duration reinforces the significance of common open space, and increases the likelihood of changes in future design requirements. Similarly, existing open places in cities will likely be subjected to the transformation, both in terms of spatial-physical characteristics and the offered contents, as the pandemic revealed their current weaknesses [116] such as insufficient area, uneven distribution, or unequal accessibility to green areas [11,94]. In spring 2020 in France, for instance, the maximum allowed radius distance from the residence (2 km) disabled the access to open green spaces for many urban dwellers [117]. In cities where green areas were closed, the citizens were jogging and exercising on pedestrian walkways, bicycle lanes, and even on traffic roads, which in some cases resulted with overcrowding and interpersonal conflicts [116]. Inadequate and uneven accessibility, and inadequate characteristics of public space raise the probability of developing risk behavior and violating social norms and regulations in future crises, too [118].

A special challenge in (re)designing common open spaces resilient to massive infectious diseases will be to determine their capacity, i.e., to define the safe number of users at a given time, and the size [95]. Although design solutions to this problem have already been offered, e.g., social distance circles in Brooklyn Park, New York's Domino Park, or San Francisco's Dolores Park [1], the Rimbin "infection-free" playground concept [119], or socially distant yoga domes [120], etc., they are considered linear when observed in the long term. Therefore, the results of sociological, psychological, and cultural studies that focus on basic human needs, e.g., [121,122], should also be included into future 'infection-free'

and more permanent design solutions. In the narrow spatial sense, however, this refers to increasing the number of open spaces (such as by transforming conventional roofs into green roof gardens), their interconnection, and/or increasing the area of individual existing spaces. Mentioned interventions should be carried out in accordance with microclimatic conditions (air movement and wind, temperature, direct exposure to the sunlight, humidity, etc.) which, according to new findings [123,124], may be in favor of or to the detriment of infection control in public space. Some technological solutions, such as the applications that show space occupancy at a given time, can help users to find their spot in public space and take part in an activity [125]. At the micro level, the design of urban furniture, hygiene stations, materialization, etc., are becoming increasingly important.

Furthermore, an increasing demand for open space, especially in densely built-up urban areas, places pressure on traffic surfaces, indicating that various organized transformations within the existing traffic matrix can be expected in the coming period, from permanent or periodical conversion of roads into pedestrian and bicycle routes, to permanent or periodical conversion of parking spaces into green or gathering areas. Giving the priority to pedestrians and cyclists represents a step towards the general betterment of the quality of life in cities [1]. On the other hand, if the trend of increasing the use of private vehicles continues in the future (in a negative scenario), it may be required to introduce policy measures, such as car use bans [1], i.e., to intensively stimulate the alternative forms of mobility, such as shared drives, shared car ownership, or micromobility [126,127].

Due to changing conditions and needs, adaptive capacity is becoming an increasingly important indicator of successful open space shaping [3,116,128]. Many functions and activities that are typically performed indoors were moved to the open following the onset of the COVID-19 crisis [129].

4.2. Urban Contents

The majority of researchers studying the effects of COVID-19 on urban environments agree that the preservation of high urban density in the post-pandemic time will simultaneously require both the densification and the diversification of urban contents, in order to regulate connectivity and mobility, and to prevent overcrowding in open and closed spaces. To that end, the leading emerged concept of pandemic-resilient spatial organization refers to mixed land-use planning, substitution of spatial models of concentration with the models of dispersion [130], and the design of multifunctional spaces and places. A way to reach this goal is to design functional strategic [131] and everyday [89] spaces that are highly flexible, thus transformative, and responsive to changing needs and new potential crises.

In the published body of research, the neighborhood is often treated as a territorial scale at which the diversity of densely distributed urban contents needs to be accomplished. Reduced mobility and the increased range of home-based activities, such as distance working and online shopping, likewise raise the need for third social places within the neighborhoods [132].

The examples of proposed mixed-use neighborhoods feature a combination of functions, from residential, to commercial, to industrial, to recreational, to social. Such a functionally enriched model, however, further needs to be adjusted to the variety of generational, cultural, and occupational needs [94] which altogether poses a complex planning and designing task for 'complete', i.e., compact, walkable neighborhoods encompassing all services that one needs in a sustainable urban environment [133].

4.3. Closed Space (Re)Design

The COVID-19 pandemic changed the way in which users occupy built closed space, and imposed new demands to building design. In the literature, flexibility [134] and the applied principles for healthy, safe, and sustainable [135,136] building design have become the key general qualities of virus-resilient built space. At the same time, several international systems for the assessment of the 'immunity' of buildings towards infectious diseases, e.g., [137,138], are being developed.

With the COVID-19 crisis, the advantage of individual over collective housing was emphasized. As a result, different debates on the re-examination of existing housing typologies, e.g., [92,139–142], have been launched. The residents of houses had an exclusive and unrestricted access to the private open space, and usually a higher level of spatial comfort which was useful for keeping the prescribed physical distance and maintaining the isolation period more easily. At the same time, the residents of flats were struggling to maintain COVID-19 rules in a limited closed space. Apartments with small area per user [143], or without private semi- or fully-open spaces (such as balconies and terraces) [144], as well as the apartments with poor visual contact with the outside [145], were marked as particularly unfavorable.

However, the development of multi-residential housing will be continued undoubtedly. To that end, several identified guidelines for future design and construction of this type of residential buildings are provided below (Table 1). The application of the listed design measures will improve the safety and comfort in crisis-related situations, and contribute to overall improvement of the quality of living space, simultaneously.

Table 1. Design guidelines for post-pandemic multi-residential buildings.

Measures	Guidelines
Accessibility to (semi)open spaces	Equip residential units with a good-quality access to open or semi-open functional surfaces [146,147].
Size of the (semi)open space	Maximize the surface of free open space on the building lot. Increase the size of private open or semi-open space such as balconies and terraces. Introduce additional joint open or semi-open space within the building, e.g., at the building roof [141], or within the atrium.
Application of nature-based solutions	Maximize the presence of greenery on the building lot. Apply integrated green systems within the balconies and terraces. Integrate micro food production systems [148]. Introduce green systems into common indoor spaces.
Visual connection between indoor and outdoor space	Establish a high-quality visual connection between the indoor and the outdoor space [149,150], through building envelope, by providing windows of sufficient size, position, and other adequate characteristics.
Third places' introduction	Provide the experience of social environment within the building system in case of prolonged indoor stay [145], e.g., by introducing the third places' activities.
Indoor comfort	Ensure that the comfort of a residential unit is suitable for living under emergency conditions. Consider the size of home and of its parts intended for prolonged stay. Consider the potential of dividing home area into several sub-units that can be used independently, e.g., [151,152]. Design (flexible) living space that can provide conditions for work and studying from home. Increase the size of the kitchen, and the number of bathrooms. Increase the size of home storages in the case of blending living, working and learning [148]. Provide excellent indoor air quality, primarily by applying the passive ventilation mechanisms. Maximize natural light, introduce direct sunlight into a living space through enlarged openings in building envelope [153], and reduce the presence of solar control elements.
Joint indoor communications	Consider increased corridor width, staircase size, and the number of elevators [142,151].

Table 1. *Cont.*

Measures	Guidelines
Materialization and hygiene	Apply natural materials to promote biophilic attributes of closed living space [154]. Consider introducing a spatial sanitary barrier at the entrances of building and the flats [148,155]. Use non-porous and smooth materials that represent a less stable surface for pathogen growth, and are easy to sanitize and maintain [122,156].
Furniture	Plan modular furniture allowing for easy spatial transformation. Plan multipurpose furniture elements. Plan furniture that can be easily sanitized.

In non-residential buildings, the main highlighted problem concerns the number of users in a single common, enclosed space. As a result, these buildings are seen as places at high risk of virus transmission and are consequently subject to many restrictions on use, especially during peak pandemic periods. As expected, new guidelines for the design of public buildings (Table 2) concern primarily the control of distances and densities, and the presence of public health risks [1].

Table 2. Design guidelines for post-pandemic non-residential buildings.

Measures	Guidelines
Open space	Plan yards for smaller number of users. Introduce atria, balconies, terraces and other (semi)open spaces into building layouts. Enable utilization of roof space. Plan outdoor activities, such as office work, meetings, and socializing.
Spatial organization	Design spaces for smaller number of users. Reconsider the use of the open plan office systems. Design flexible office space and plan mobile partition walls. Secure sufficient distancing between the users.
Indoor communications	Consider increased entrance area, corridor width, size of staircases and the number of elevators. Direct users' movement, e.g., by separating entrance and exit points at station buildings.
Space flexibility and transformability	Design spaces that can be converted to other purposes [142,157]. Design multifunctional spaces.
Indoor air quality	Integrate UV light within ventilation systems [123]. Increase ventilation rates and keep the ventilations systems on all the time. Establish a maximum number of users in specific ventilation zones. Clean ventilation systems and replace filters frequently. Reconsider air recycling vs. fresh air intake. Regularly monitor air humidity and conditioning water-based systems. Allow for natural ventilation.
Nature-based solutions	Introduce living systems into buildings, from green gardens and walls, to desk terrariums. Design green building envelope. Provide accessibility and at least visual contact with the greenery.

Table 2. *Cont.*

Measures	Guidelines
Daylight	Maximize natural light in indoor space: enlarge window openings, plan atria, reduce the use of solar control elements, etc. Increase the penetration of direct sunlight.
Materialization and hygiene	Provide sanitary barrier at the entrance of the building [148,155]. Provide transitional sanitary spaces within the building. Provide sanitary points. Apply natural materials to promote biophilic attributes [154]. Use materials that represent a less stable surface for pathogen growth, and are easy to sanitize and maintain [122]. Pay particular attention to high-contact areas and surfaces.
Furniture	Plan modular furniture allowing for easy spatial transformation. Plan furniture that allows for physical distancing. Plan furniture that can be easily sanitized.
Smart building systems	Apply touchless technologies. Monitor air quality. Monitor users' presence and flows [158].
Digitalization	Enhance digitalization, e.g., by transforming physical into virtual museums and galleries [159].

5. Discussion and Conclusions

This review deals with the emergence and evolution of changes in the city space caused by the COVID-19 pandemic. It presents an overview of registered space-related manifestations within the different segments of urban environment, provoked by national, regional, or local regulations or voluntary recommendations applied in order to slow down the transmission of the virus, and the adaptation of urban residents to new circumstances. Both the introduced measures and the human adaptation that emerged in their response resulted in rethinking future city development scenarios that provide resilience to new potential pandemics. By that, finding a way to design a 'safe' space that concurrently satisfies all basic human needs, now and in future, became a key challenge for urban designers and architects who are shaping today's cities. Solving this complex spatial problem with two equally emphasized and opposing focal points, however, will not be possible without clear manifestation of the impact of COVID-19 crisis on the steady way of life in the city. As this impact has not been fully displayed yet, the long-term influence of the COVID-19 pandemic on city-shaping can at the present moment be considered at the level of speculation, and, indeed, the reviewed body of literature points to often conflicting views and visions of the post-COVID-19 city. The exception is operationalized through several spatial themes on which the most authors have reached a consensus. These topics concern open urban spaces, residential and public building spaces, and urban contents.

Following the definition of descriptive guidelines in Section 4 of this review, the attempt was to identify the precise numerical values that would accompany them. Here, however, a significant limitation has been encountered. Namely, the so-far published literature does not offer new spatial indicators and standards that would inform post-COVID-19 architectural and urban design, but the need for these has been emphasized by some authors, e.g., [160,161]. Again, a current lack of post-COVID-19 design indicators (except for those based on physical distancing measure, e.g., [162]) can be explained by the still ongoing COVID-19 crisis, and, to that end, some authors, e.g., [142,163], believe that it is still too early to bring definite conclusions on the effect of COVID-19 on design. Altogether, existing constraints open a new research subject for the future, that is the establishment of precise design indicators and spatial standards that would concurrently build city resilience to potential pandemics and improve the overall quality of city life.

Common denominators for available, descriptive post-COVID-19 design guidelines are adaptability, flexibility, and transformability. It can be concluded that these three partially overlapping qualities represent the robust margins of a safe city, thus the preconditions for achieving the resilience of the city space.

Author Contributions: Conceptualization, S.K., O.L.G. and B.F.; methodology, S.K. and B.F.; investigation, O.L.G., N.N., B.V. and A.M.; resources, O.L.G., N.N., B.V. and A.M.; writing—original draft preparation, O.L.G., N.N., B.F., B.V., A.M. and S.K.; writing—review and editing, S.K.; visualization, O.L.G. and N.N.; supervision, S.K. and O.L.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors express their gratitude to Reviewers and Editors of the journal Sustainability for timeliness, good collaboration, and helpful comments.

Conflicts of Interest: The authors declare no conflict of interest.

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