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Designing for COVID-2x: Reflecting on Future-Proofing Human Habitation for the Inevitable Next Pandemic

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Abstract: The COVID-19 pandemic of 2020–2022 has revealed the vulnerability of modern society to a highly contagious airborne virus. Many spaces in the urban and built environment designed during the late twentieth and early twenty-first century are ill-suited to maintain the level of social distancing required to reduce the probability of virus transmission. Enclosed spaces—in particular, communal circulation spaces such as corridors, elevators and lobbies—have proven loci of transmission, together with circulating reticulated air and lack of proper ventilation. While urban planning needs to incorporate the lessons learnt during COVID-19 in order to future-proof our communities through the provision of well-designed greenspaces, the main burden will fall on architects, who will play an instrumental role in designing buildings that are fit-for purpose. This conceptual paper reviews the status quo and discusses a number of strategies to future-proof human habitation for the inevitable next pandemic.

Keywords: COVID-19; infectious diseases; pandemics; housing; sustainable architecture; urban design

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1. Introduction

Within the first three months of January to March 2020, COVID-19, the disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1], rapidly developed into a truly global pandemic, affecting every continent. With its rapid spread and cross-sectorial impact, the COVID-19 pandemic has proven to be a social and economic disruptor on a global scale not seen since the "Spanish flu" pandemic of 1918–1919 that cost between 17.4 and 50 million lives [2]. At the time of the final revision (2 July 2022) 552.5 million people had been infected on all continents in all countries, and the global death toll was 6.34 million [3].

Currently, vaccines developed by various pharmaceutical companies are being administered to contain COVID-19 [4] against a backdrop of various levels of community resistance to vaccination [5,6], and efficacy against newly emerging strains [6]. It can be posited that, setbacks notwithstanding, the world is gradually moving towards a post-pandemic reality. Thus there is an increasing need to consider the post-pandemic realities: will we return to "business as usual," interpreting the COVID-19 pandemic as a blip? Or should we recognize COVID-19 not only as cross-sectorial social and economic disruptor, but also as an opportunity to re-assess and reconsider current patterns of living, studying, working and commuting in order to future-proof human habitation for COVID-2x?

Clearly, much of human behavior in the post mask mandate era, at least in the developed countries, has resulted in a return to a "business-as-usual" approach, the rising number of infections notwithstanding.

For many early commentators, COVID-19 was an unforeseen occurrence, a "black swan" event. After all, in the minds of the public, the last global pandemic, the "Spanish flu" pandemic of 1918–1919, which cost between 17.4 and 50 million lives [2], had long receded into the depths of history. Yet, COVID-19 was not a "black swan" event, as the emergence of a SARS-like coronavirus was in fact predicted by public health professionals [7]. Critical in this equation is the fact that COVID-19 is only one, albeit the most recent and most severe event in the SARS-CoV (2004), MERS-CoV (2012), SADS-CoV (2016) and SARS-CoV-2 (2019) trajectory [8,9]. From an epidemiologist's perspective, it is predictable that SARS-CoV-2 will not be the last zoonotic coronavirus to emerge and that COVID-19 will not be the last pandemic. Indeed, zoonotic coronaviruses akin to SARS-CoV-2 are currently in existence in various host species [10–12]. With a high degree of certainty, some of these coronaviruses will emerge as a yet another major threat to humans [13], which may well manifest themselves in the foreseeable future as an epidemic or even pandemic [14].

What follows is a *conceptual* paper that identifies and discusses some of the issues arising from building design and usage during the COVID-19 pandemic and which lessons can be drawn on to future-proof human habitation and living for the inevitable next pandemic. As such then, this paper does not follow the standard IMRAD pattern of research papers. It first summarizes the experiences of living through COVID-19 outbreaks and discusses some conceptual and planning frameworks to be considered.

Where necessary, the paper touches on issues of urban design and urban planning, but only to contextualize the various design imperatives.

2. Experiences of Living through COVID-19 Outbreaks

As the COVID-19 disease quickly developed into an epidemic, which soon morphed into a global pandemic, national and sub-national (state) governments engaged in measures to contain or at least to slow its progress and to ensure that their public health system was not overwhelmed by cases requiring hospitalization. These included border closures (international and interstate) to prevent or reduce the likelihood of seeding events into and within a country [15,16]. To curb community transmission, stay-at-home orders were implemented, on occasion amplified by curfews, by limiting unnecessary movement and mingling of people in shops and public gatherings [16,17]. These were augmented by social distancing measures and mandatory wearing of fitted face coverings ("face masks") [18]. Compliance with these rules relied on personal responsibility and group pressure [16]. As the world grappled with adjusting to dealing with the disease, new strains of SARS-CoV-2 evolved. Some strains, in particular Omicron, posed new challenges, as it proved to be more infectious [19,20].

2.1. Effects of Stay-at-Home Orders

While in theory stay-at-home orders should have effectively curbed community transmission of SARS-CoV-2, the system was permeable and open to abuse [16]. A feature of the stay-at-home orders was that some movement remained permissible, such as shopping for food, undertaking exercise, providing care or assistance to vulnerable persons and seeking medical attention, including obtaining a COVID test or receiving a COVID vaccination [17,21]. While employers were directed to allow their staff to work from home where feasible [22], people engaged in essential services, such as food retail outlets, supply chains or healthcare, were required to continue to work at their accustomed places of employment [23]. If infected with SARS-CoV-2 at their workplace, they seeded the virus into their household and throughout the workplace.

At this point, socio-economic variables came into play. Residents with higher socio-economic indicators not only tend to live in less crowded conditions, but also have the financial capital to self-isolate (as mandated) and offset any impact this may have on childcare or income. Residents with lower socio-economic indicators do not have the capital to self-isolate as they tend to occupy less well-paid retail, service and supply chain positions [24]. They also often face situations where large families reside in the same dwelling, sometimes with multiple essential workers cohabiting together, but as they commonly work for different employers at different locations, their vulnerability and exposure is elevated. Exacerbated by culturally conditioned (albeit formally illegal) visits by members of multi-household extended families, particularly among immigrant communities, this not only increased exposure to infection, but also increased the potential for onwards seeding of local clusters. Not surprisingly, then, major COVID-19 clusters emerged in many low socio-economic neighborhoods with high incidences of crowding [25–29].

2.1.1. Architectural Design Issues

Extant housing, in particular the open-plan house designs that were en vogue since the 1970s [30], replete with centralized ducted air conditioning pushing reticulated air throughout the rooms, were not conducive to self-isolation inside a family dwelling [31]. Consequently, infection among family members was high, particularly during the winter months when windows remained shut to preserve heating, but which at the same time prevented external ventilation [32–34].

Open-plan offices, particularly those with desks arrayed in linear patterns, were susceptible to the spread of COVID-19 among co-workers, as shown by an early epidemiological study of a call center in Seoul [35].

Of considerable concern for the public were enclosed, communal circulation spaces, such as lobbies, corridors and elevator cabins. The majority of apartment and office buildings were erected at a time when the concept of social distancing was purely defined in terms of culturally appropriate inter-personal spacing [36], rather than defined by epidemiological considerations [37].

2.1.2. Mental Health Issues

In addition to a reduction in physical mobility, the stay-at-home orders ("lockdowns") exposed some members of the community to a higher level of psychological stressors leading to potentially harmful interpersonal and environmental stimuli, including domestic violence and abuse, and deteriorating family relationships [38,39]. Disproportionately at risk were people with disability or with pre-existing health issues such as non-communicable diseases or poor mental health; people who were homeless or were living on their own, often with reduced communication and limited social networks beyond their work settings [38,40]. The pandemic both exacerbated existing mental health conditions [40–43] and created and intensified inequalities [39,43–46].

Many communities prohibited the use of small neighborhood ("pocket") parks that commonly provide community members with greenspace amenity and mental stimulation. The major concern at the time of the pandemic was that these spaces encouraged social interaction, while appropriate social distancing could not be guaranteed [47,48]. These green-space closures impacted disproportionately on vulnerable community members resulting in an increased strain on mental health.

2.2. Effects of Social Distancing Rules on Hospitality, Shopping and Commuting

By and large, the design of existing stores, hospitality venues and public transport units (buses, trains) was based on high turn-over and customer density models maximizing floor space use, with little concern for air circulation beyond the mandated air replacement over a set time period. To reduce the risk of community transmission in these settings, many countries imposed social distancing rules, mandating minimum interpersonal spacing. These ranged from 1 m as initially recommended by the World Health Organization [49], to 1.5 m in China [50], and 2 m in the United Kingdom [51] and Korea [52]. Australia, for example, settled on 1.5 m interpersonal spacing and an equivalent density of one person per 4 sqm for indoor venues [53]. Other countries imposed differential levels of distancing based on activities [54]. In addition to imposed levels of social distancing, inter-personal spacing changed due to personal agency [55], although this was highly dependent on individual perceptions of personal vulnerability to the virus.

In indoor venues such spacing was enforced by reducing seating through the removal of tables and chairs, the blocking of fixed seat options, or via signage on the floor and on seats [56].

2.2.1. Hospitality Venues

In indoor venues interpersonal spacing was enforced by reducing seating through the removal of tables and chairs [56]. Depending on the nature and extent of movement restrictions, many hospitality venues switched from indoor dining to "black" kitchens solely serving take-away meals to remain "open" and enable income, resulting in a concomitant growth of the food delivery industry (e.g., MenuLog) [57,58].

2.2.2. Shopping

At the same time, many shoppers reduced their personal exposure with an increased uptake of drive-through, online order and supply services via "click-and-collect" at the store and via store-to-door parcel delivery [59–61]. Many shops regulated the number of customers that could be present on the premises at any point in time.

During the COVID-19 pandemic, likewise all supermarkets controlled the density of shoppers by regulating customer numbers in the store at the time (in keeping with the mandated one person per 4 sqm rule) and provided guidance on aisle use through signage [56].

The internal layout of most supermarkets is designed to maximize the use of the available floor space. Consequently, most aisles are just wide enough to allow two shopping trolleys to pass each other. The mandated width varies between jurisdictions, ranging from un-legislated as in the Australian situation [62] to 0.9 m in Germany [63], 1.07 m (42") in the USA [64] and 1.2 m in the United Kingdom [65]. These widths are too narrow for two shoppers to pass while adhering to the social distancing guidelines of 1.5 m between people.

Experiences with the Delta and Omicron strains of COVID-19 suggest that even short-term contact, such as when passing in a shopping aisle may lead to infection [20]. Consequently, at the height of pandemic, many shoppers avoided entering aisles which already had people in them.

2.2.3. Commuting

Very early in the pandemic, infection risk in transportation was seen as a concern, with ventilation and seating density identified as the key parameters [66–68]. On buses and trains the latter could be readily addressed by ensuring that some seats remained unoccupied, even though this reduced revenue. In public transport, seats deemed "off-limits" were marked with large adhesive stickers [56], but compliance relied on personal responsibility and group pressure. The real, or perceived, risk of infection due to prolonged exposure in confined environments with limited air circulation as in the case of public transport [66,69], resulted in an increased private vehicle use [70,71].

2.3. Hotel Quarantine and External Seeding Events

The Australian and New Zealand governments, which embraced a strategy of eradication during all of 2020 and the first half of 2021, successfully contained, suppressed and then eradicated various seeding events brought into the country from overseas. Facilitated by their international borders being closed to all but commerce and repatriation of national citizens, this was performed easier by the fact that both countries are bound by sea with limited points of entry (airports, seaports). A public health education failure in Sydney in June 2021 led to the successful seeding of the Delta strain of SARS-CoV-2 [20], which could not be contained and led to large outbreaks in New South Wales and Victoria [72,73]. While seeding into the other Australian states could remain contained until November 2021 through the closure of domestic state borders [15], a seeding event into New Zealand was "successful" [72]. The subsequent seeding of the Omicron strain in December 2021 with its high level of infections performed suppression impossible.

During the early period of COVID-19, commercial hotels in several countries were "converted" into quarantine facilities. There, business travelers and citizens repatriated from overseas had to sit out a 14-day quarantine period, coupled with frequent testing, to ensure that they were virus-free before being allowed to mingle with the wider community [74]. These "conversions," which found the support of the industry [75,76], were largely limited to modified check-in and house-keeping processes, room food delivery and movement restrictions of quarantined persons (monitored via guards on the floors) [74]. Despite these precautions, several instances were reported where infection occurred between rooms, primarily on the same floors [77]. Of the 255,600 residents returning to Australia between March 2020 and March 2021, for example, 3400 tested positive to COVID-19. Several of these were infected *while* in quarantine [78].

While some of these infections were due to protocol and process failure, including human misbehavior on the parts of guards or passengers, the majority were caused by design constraints of the pre-existing buildings. As with residential apartment complexes, common areas, such as reception spaces, hallways and lifts, were implicated. Ventilation issues were identified as the primary causal factor [79–81]. In addition to transmission between quarantined individuals, some system failure led to seeding events into community [78].

Such issues did not present themselves in buildings that had well ventilated external stairwells and external access corridors to the units. Importantly, residents of such designs exhibited a lower sense of vulnerability to infection [82].

2.4. Early Detection Systems

One of the success stories in the initially successful Australian attempts at suppression and eradication of COVID-19 seeding events was the testing of urological wastewater for the presence of SARS-CoV-2 virus fragments [83–85]. This allowed for the early detection of the virus circulating in a community before it could be documented through standard COVID-19 swab testing of individuals. The efficacy of the technique was determined by the suitability of an urban sewer system/network to permit spatially stratified sampling of the wastewater stream. The majority of systems, however, were not designed for such interceptions.

3. Conceptual Framing for Future-Proofing Human Habitation

At the outset it must be made clear that it is impossible to holistically and completely future-proof a community against the impact of another pandemic that is caused by a contagious, airborne disease. There are too many variables at play, ranging from existing inadequate building stock that cannot be replaced economically or upgraded due to cultural reasons (e.g., heritage buildings), through to behavior patterns of individuals in post-liberal societies who are unwilling to conform with public health requirements, irrespective of their relevance to the common good.

What can be done, is to develop policy levers and planning controls that establish the foundations for post-COVID urban design, transport planning and architecture. The following will advance some conceptual parameters for this discussion.

At least in the more affluent countries, the COVID-19 pandemic has effected, or at least accelerated, a pivot to a world that is dominated by digital technology with the virtual delivery of school and university education [86–89], museum experiences [90,91], film festivals [92,93] and seasonal festive markets [94]. The major pivot has been towards working from home where feasible [95–97] and an increase in on-line commerce including groceries [98–100].

As many countries have moved from a policy of containment and eradication to the concept of "learning to live with COVID," many employers, who initially out of necessity embraced and even mandated a working from home policy, have been walking back on this, as they are uncomfortable with a perceived lack of control [101], often demanding full-time physical presence at the workplace, or they have developed hybrid models [101,102]. Arguments for full-time physical presence range from collegial dynamics to the fact that rented office space stays unused [103]. As employers pivot back to pre-pandemic concepts of work, physical spaces will remain in demand for all activities and thus will require adaptation to meet the challenges of a future pandemic. Calls have been made to capitalize on COVID-19 as a major disruptor and to refocus architectural design, housing policy and urban planning towards greater sustainability and livability [104,105]. Importantly, this endeavor is not confined to the affluent countries, but global [105].

The key conceptual parameters to be considered are (i) containment through compartmentalization and (ii) ventilation. Ideally, the designs should be such that they fulfil the aspirations of a community for living and working while at the same allow for risk minimization in the event of a future pandemic.

3.1. Ventilation

Appropriate design of ventilation needs to be regarded as a necessity—cutting across all post-pandemic architecture, regardless of the function on the building [106]. At present, all air-conditioning units are based on reticulation of the air with limited adding of fresh external air to the mix. The majority of air returns tend to be ceiling mounted, resulting in an upwards extraction of expelled air. This is facilitated by the fact that exhaled air tends to be warmer and thus can be readily displaced by cooler air sinking to the bottom of a room [107]. Consideration should be given to rethink this approach and to favor floor-level air returns. Numerous studies have examined the aerosol dispersal during normal activities such as speaking, shouting, singing and physical exercise; and during coughing and sneezing [108–110]. Aerosols are heavier than ambient air with the droplet size determining the residence time [110,111]. If the reticulation of air inside rooms is directed downwards, then the residence time of aerosol droplets at the nose- and mouth-level of standing and seated persons is likely to be reduced.

Where possible, only fresh external air should be inserted into the system, rather than reticulating existing air. It is appreciated that this may incur additional heating and cooling costs that standard reticulated air (with its admixture of a mandated percentage of fresh air) would not. In cases where the use of standard reticulated air is deemed necessary due to heating costs, all air should be sent through a HEPA filter (MERV-17+). Additionally, to minimize risks due to system failures, the design should consider separate air cycles for communal spaces (i.e., circulation spaces) and for private spaces (e.g., hotel rooms, family rooms/bedrooms and individual offices).

3.2. Contained Internal Spaces for Living

Even though in some climates al fresco living is an option, at least during some part of the year, the majority of human habitation and work occupation occurs in enclosed spaces with various levels of air exchange.

3.2.1. Residential Developments

For most people, residential spaces, be they flats, apartments or stand-alone houses, define and enclose their personal world with their possessions. These spaces are used for sleeping, living and socializing among personal circles. Elsewhere, design options have been discussed that conceptualize a zoned dwelling with a containment area as an interface between an uncontrollable external and a controllable internal space. The internal space was comprised of spaces reserved for the immediate family and a space to be used by visitors and houseguests (Figure 1). These spaces were compartmentalized through doors and separate ventilation systems. The master bedroom was designed as a potential self-isolation space with external (garden) access for provisioning and laundry extraction [31].

Some post-COVID designs see the use of multiple bathrooms, ideally one per bedroom, in order to increase personal amenity, while at the same time limiting the use of shared sanitary facilities. While such approaches may be possible for the affluent segments of society, they are quite unrealistic for the majority. Globally, there is an increasing demand for affordable housing with one- and two-bedroom designs. This requires adaptive thinking (Figure 2).

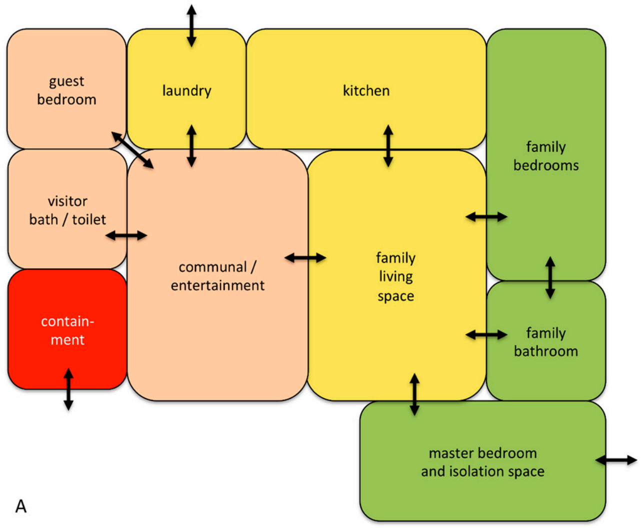

Figure 1. Conceptualizing internal zoning of domestic multi-bedroom dwelling spaces to compartmentalize exposure to infectious agents: (**A**) internal connectivity; (**B**) airflow directions. (Adapted from Ref. [31]).

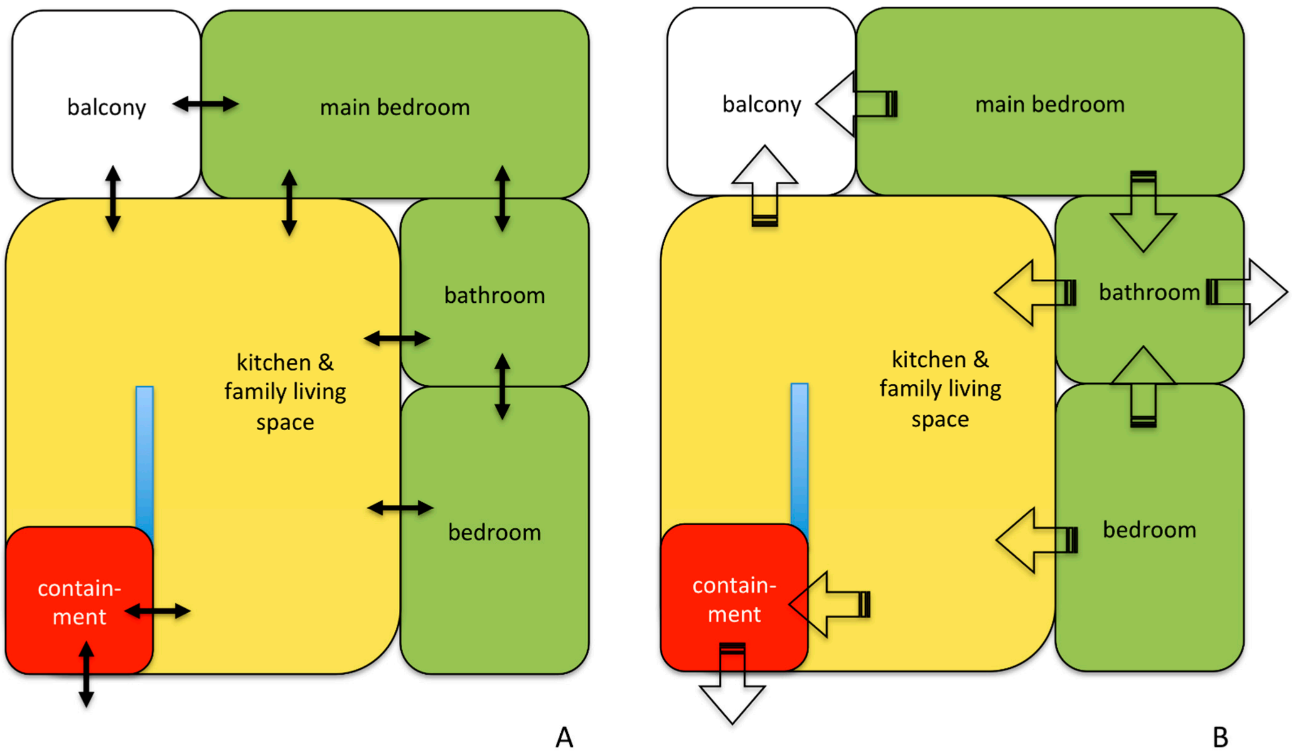

Figure 2. Conceptualizing internal zoning of domestic of two-bedroom dwelling spaces to compartmentalize exposure to infectious agents: (**A**) internal connectivity; (**B**) airflow directions.

3.2.2. Hotel Developments and Multi-Residential Complexes

Traditional, single or double story motel developments are comprised of a series of rooms coming off external communal spaces (Figure 3) where the infection risk is low. As such designs are impractical in high-density urban centers with high land values, multi-story designs are required. Multi-story apartment developments of the 1940s to 1970s often have external stair wells and communication corridors. Likewise, some hotel developments of the 1970s to 1990s have large internal lobby air wells that reach all floors, with rooms coming of corridors open to the central space. Both designs, which are well ventilated and thus reduce infection risk, are not the norm, however.

Figure 3. Traditional, 1950s style motel development with external communal circulation spaces. Astor Motel, Albury, NSW.

From an epidemiological perspective, hotels and multi-residential complexes comprise two discrete spheres: communal spaces, such as lobbies, underground parking decks, elevators, stair wells and corridors; and personal spaces, i.e., hotel rooms or private apartments. The highest probability of exposure occurs in the communal spaces—in particular, areas with high traffic volume, such as lobbies. The size of lobbies, however, tends to lower the infection risk compared to that of confined spaces, such as elevator cabins.

Key to successful infection risk management is containment and the insulation of the private sphere from the communal sphere. For the private sphere, this can be achieved by the creation of an entrance to the room or apartment designed as a containment space with sealed doors on both ends and rapid air exchange, effectively acting as an airlock if so required (Figure 4). Additional safeguards are provided by separate air cycles for communal and private spaces and by pressure differentials. The latter, created by extraction, establishes a positive flow from the private space to the containment space and from the containment space to the communal space in cases where the doors remain open for longer periods of time.

While it is appreciated that hotel developers are often reluctant to supply hotel rooms in high rise developments with windows that can be opened given the risks of items being dropped out of windows, and the risk of intentional personal defenestration, fresh air inflow is instrumental in reducing infection risk. Such reluctance is spurious, however, given that it is possible to design windows that accommodate air inflow while preventing objects being discarded.

In hotel developments and multi-residential complexes movement within floors (via corridors) and between floors (via stairwells and elevator shafts) needs to be considered. While air exchange in corridors can be managed along standard protocols, again with extraction at floor level, elevator shafts pose a risk for cross-floor contamination. This can also be minimized by pressure differentials, with continuous positive flow from the corridor into the elevator shaft through ventilation slots. The elevator cabin itself poses a major concern given the potential residence time of fine aerosols in confined spaces. Continuous inflow of filtered, lightly pressurized air from the top of the cabin and expulsion at the bottom into the elevator shaft is indicated given that passengers tend to stand while travelling in elevators. Weight sensors allow to adjust the strength of the air flow into the cabin to accommodate the level of cabin occupancy. The flow of potentially contaminated air from the cabin to the floors can be minimized through intervalometers that ensure that the pressurization of the cabin ceases just before the doors open.

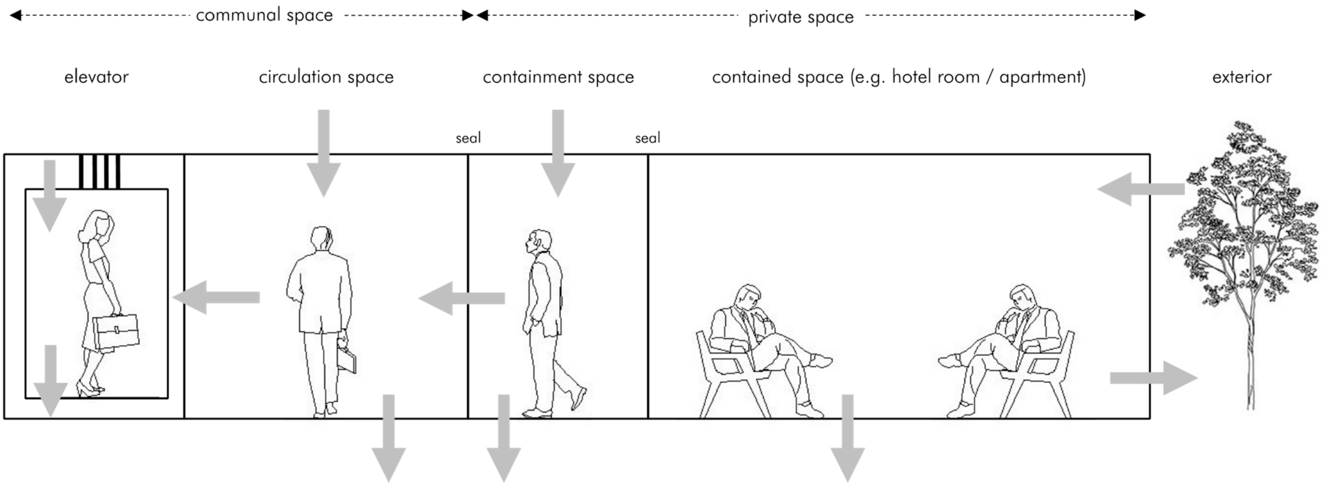

Figure 4. Conceptual model of communal and private spheres in hotel developments and multi-residential complexes.

3.2.3. Urological Wastewater Testing

Given the demonstrated success of the urological wastewater testing for the early detection of the SARS-CoV-2 virus in many communities, stratified sewer collections systems should be retrofitted into existing sewer networks where feasible and be incorporated in future developments of residential suburbs [112]. While this is mainly an issue for urban planning, fifth-order sampling points should be included in the design of large apartment blocks and residential, mixed use and pure office-use high-rise developments. These sampling chambers should allow for easy keyed access to a space in the basement that provides access to the sewer line for effortless automated or manual in-line sampling and be large enough to provide storage space for sample collection including cold storage for 50 samples in a small refrigerator [112].

3.3. Contained Internal Spaces for Working, Learning and Shopping

The open plan design has been a common feature for office spaces since the 1930s, with early designs such as Frank Lloyd Wright's 1936 design for the Johnson Wax Administration Building [113]. Such offices, like school classrooms and university lecture rooms, are characterized by large enclosed spaces with shared air. Given that SARS-CoV-2, like most other zoonotic viruses, is dispersed through expelled aerosols, such large yet confined air spaces are of concern.

3.3.1. Offices

Open-plan offices are inherently susceptible to the spread of COVID-19 among co-workers [35], with some writers predicting the end of this concept [114,115] given underlying pre-pandemic concerns of workplace confidentiality and productivity in open plan designs [116,117]. Assuming that the concept will not fade away given perceptions by management for the need of command-and-control staff management, and a lack of opportunities for the ready modifications to internal structures [118,119], consideration needs to be given to the design of ventilation. As most activity in open plan offices is sedentary, with most staff working on workstations, speaking on the phone or via videoconferencing, air should be downwards extracted either at the desk level (akin to the ventilation in nail salons) or at the intersections and nodes of desk arrays, rather than continuing the current pattern of air dispersion through the entire space (Figure 5). Flexible office layouts can be achieved in new builds by the insertion of a multiple outlet duct pattern in the floor. Alternatively, such localized air extraction can be achieved by the provision of air pillars collected to overhead extraction ducts (Figure 5). As an alternative, floor-level extraction through mid-floor grilles can be considered.

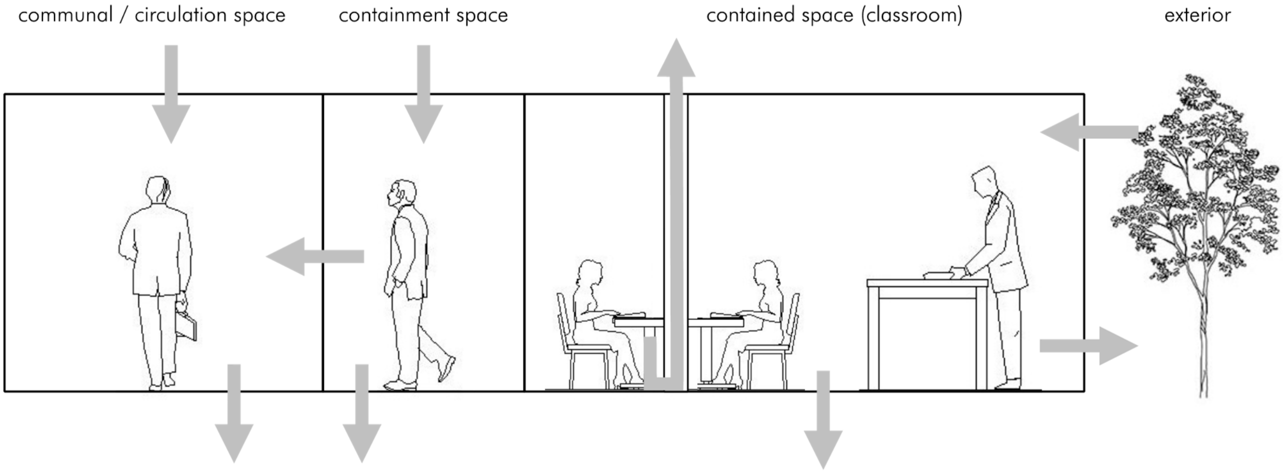

Figure 5. Conceptual model of school or office layouts with extractive vents over workspaces.

3.3.2. Schools

School classrooms are confined spaces where large numbers of pupils (usually 25–35) congregate for prolonged periods of time (commonly 5–6 sessions of 45–60 min each per day). The traditional design of classrooms is such that desks are set out in rows, U-shapes or small work islands (table groups) [120], where students collaboratively learn with little, if any social distancing. This holds particularly true for infant and junior high school settings. Most existing classroom designs of the past 30 years rely on centralized ventilation systems with recycled air exchange. While some Departments of Education and school districts mandated appropriate ventilation to limit rates of infection, many buildings cannot be readily retrofitted.

New builds for school facilities need to consider learning spaces ("classrooms") that can be adapted ad hoc and on demand to cater for different learning styles including collaborative learning patterns and circulation of students between task spaces. This includes, inter alia, the design of adjacent classrooms with moveable partition walls, where three classrooms can be reconfigured into two rooms. This provides extra space for social distancing but keeps the reduced classroom availability to a minimum. Adjusted timetabling could then allow the resultant overflow to be engaged in outdoor teaching (if climate and weather permit) or for physical education pursuits.

As with office buildings, ventilation is the key to minimize infection risk. Where fixed layouts are envisaged, desk-based extraction can be implemented akin to the model suggested for offices, while for general purpose teaching spaces floor-level extraction through mid-floor grilles can be considered.

3.3.3. Shopping

It is acknowledged that the internal layout of most supermarkets is designed to maximize the use of the available floor space with narrow and long aisles. As noted, at the height of pandemic, many shoppers avoided entry to aisles which already had a customer shopping. Others avoided physical shopping altogether, resorting to on-line ordering with shop-to-car boot delivery ("click and collect") [60,121]. Such shopping is purposeful, negating a supermarket's desire to induce impulse buys and use specific product promotion and placement.

While shopping aisles can be widened where floor space permits, standard aisle widening to 2.2 m, where social distancing of 1.5 m can be maintained by passing customers, is likely to be uneconomical. It is more appropriate to avoid long single aisles by breaking them up with the creation of a middle aisle, which has been shown not to result in a measurable loss in profits [122]. If such a design is undesirable for standard operations, shelving and aisle design should be such that in times of a pandemic the store can be easily reconfigured to a middle aisle layout by taking out shelving units half-way along each aisle.

3.4. Healthcare Facilities

There is an abundance of literature on the design of healthcare facilities, particularly the design of general wards and infectious disease and isolation wards, which need not be repeated here [123].

One of the lessons taught by the COVID-19 pandemic, however, was the demand the disease placed on existing facilities, with a high number of often prolonged hospitalizations, with many patients requiring ventilators. This resulted in numerous wards being converted into ad hoc COVID wards, and the construction or establishment of field hospitals and other temporary facilities to cater for the demand [124]. Future hospital developments, and future renovations should design *all* wards in such a fashion that they can be converted at short notice into infectious disease and isolation wards.

Numerous hospitals, even recent builds, were designed without containment spaces for walk-in patients and visitors, without internal containment options between wards and without containment options in emergency departments. Some of these had to be retrofitted with temporary external extensions, whereas in other cases all elective surgery, for example, was cancelled as a precaution. Future design needs to incorporate containment spaces for walk-in patients and reconsider the spatial layout of wards, operating theatres and emergency departments to ensure that the normal functioning of a healthcare facility is safeguarded while at the same time being able to cater for high numbers of infectious patients. As with other facilities, compartmentalized ventilation management with well-thought-out pressure differentials is paramount.

3.5. External Spaces of Multi-Residential Complexes

The public response to the COVID-19 pandemic has shown the value of public parks and urban green spaces. The relevance of these to people's physical and mental health has been the focus of numerous studies [125–127]. The argument has been made that the design of urban green spaces needs to be reconsidered for the post-pandemic era [40,128] and that a stratified set of urban green spaces with increasing complexity and diversity of recreational options is required. For the most highly accessible and heavily utilized class of pocket parks design concepts have been proposed to see an inclusion of social pods, each 4×4 m, which are confined by low, but non-traversable 1.8 m wide plantings (Figure 6). This concept can be readily adapted for public external spaces in apartment complexes. During normal use, these serve for day-to-day recreation, but in pandemic times provide the opportunity to socialize and recreate in a safe, socially distanced fashion.

One of the main features of the public health response was the rapid deployment of pop-up facilities for community wide-spread nasal and throat swab testing. These were established in community facilities and in temporary structures erected in carparks, abandoned building sites and open community spaces [124]. Conceptually, the design of public open-air spaces in future multi-residential complexes can include covered spaces with open sides that during "normal" times allow for social activities sheltered from the elements (rain, sun) but that can, when fitted with marquee-like soft walls, function as well-ventilated walk-through testing centers if and when the need arises.

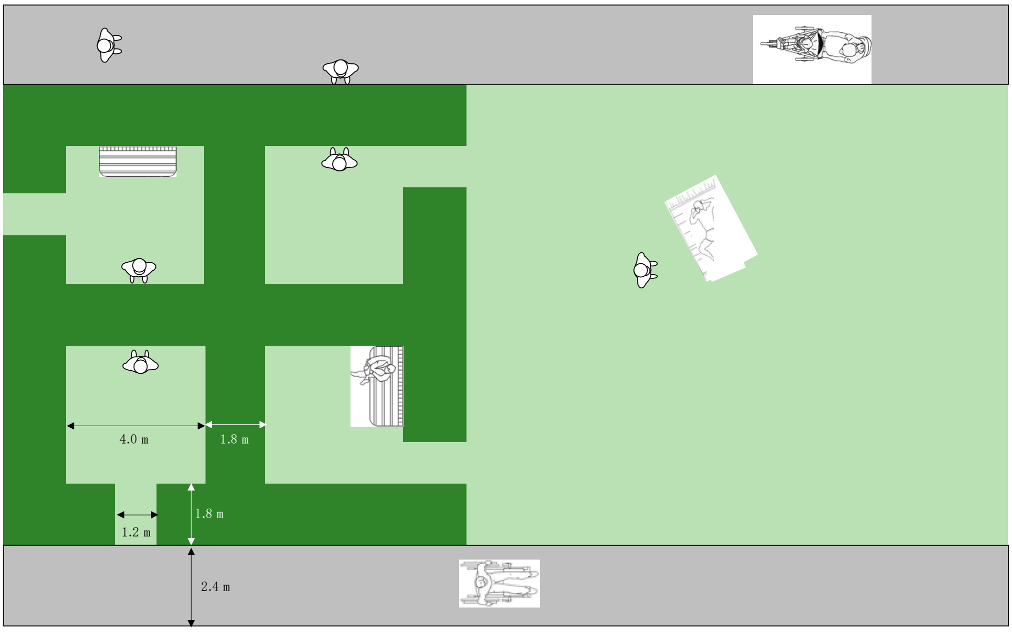

Figure 6. Design concept for value-adding to pocket parks by providing social pods (Adapted from Ref. [128]).

4. Conclusions

COVID-19 has taught humanity a valuable lesson of the fragility of the functioning of our built environment, a lesson that came at great cost to human life, people's health, people's livelihoods and the national economies of most, if not all countries. The accounting of the human cost is still ongoing. As noted, not only have over 552.5 million people been infected globally, but their partners and family were often required to self-isolate for the duration of infectiousness, which added to the enormous social and economic costs.

Rigorous planning and permissions frameworks can ensure that some of the lessons learnt from COVID-19 can be incorporated into urban open space design and transportation systems. Further, the design standards for communal facilities such as schools, community centers and healthcare facilities can be reassessed and updated to reflect the needs for better and compartmentalized ventilation, as along with flexible room design to allow adjustment for social distancing if and when required. Governments at all levels need to take the lead. Sufficient policy levers exist that can be applied to achieve positive outcomes, subject to political vision and will.

While it is acknowledged that floor space, with the associated construction, heating and cleaning costs is at premium for supermarkets, businesses need to consider the losses incurred when the density of shoppers is to be reduced during a pandemic. For new builds, and for shop refits, formal inclusion of half aisles or readily removable shelving to create half aisles ad hoc should be considered, as alongside the option of increasing aisle spacing at the expense of formerly open design areas (in the fruit and vegetable sections, for example).

It is the personal agency of future homeowners and the personal agency of developers of future hotel and office complexes, however, that can effect major changes in how we live and work, and where we spent to greatest amount of time in any given day. It is this personal agency that defines to what extent newly built dwellings will be resilient against the effects of future pandemics.

It needs to be acknowledged that the majority of individual future homeowners will not be in the economic position of being able to afford an individual architect to design bespoke homes. Rather, they are likely to utilize extant designs offered by developers and will buy "off the plan." It will therefore be the individual agency of the developers of housing estates that play a pivotal role. Statewide minimum design standards and local-level development control plans are policy levers that the governments may be able to engage. Pressure to do so, and pressure on developers to proactively redesign their plans will have to come from the general public. The inertia inherent in the system will otherwise stall any innovation. The adjustment will be gradual, not only due to the existing housing stock, but also due to the large number of new builds that commenced in some countries due to COVID-19 related economic stimulus packages and that were based on pre-COVID design concepts.

It is unclear, however, to what extent the public is willing to engage in such a discussion and is prepared to embrace the required adjustment in house design. As in most communities the current pandemic has stretched well into its third year, the "COVID-fatigue" well and truly has set in [129,130], which manifested itself in a laissez-faire attitude by many citizens as soon as government enforced movement restrictions were eased or repealed. Masses mingled in confined spaces of bars and nightclubs, as well as public events, with little if any social distancing and facial protection. Examples of this could be found in Australia, England and the USA [131]. The majority of the general public appears not ready to engage in a meaningful way in planning and preparing for the next event but has the desire to return to pre-pandemic days and pre-pandemic lifestyles. This poses a great risk for human resilience against future epi- and pandemics.

Unless this inertia can be overcome, the history of COVID-19 will repeat itself in some form. All that architects and planners can do is to set in train design solutions that minimize the impact.

5. Implications

As discussed in the introduction, it is not a question of whether, but a question of when the next pandemic will impact humanity. This paper has outlined some aspects of how COVID-19 had impacted daily life and human existence, and has also put forward some suggestions as to how human habitation can be future-proofed for COVID-2x.

The history of COVID-19 will repeat itself unless:

- Architects embrace the lessons taught by COVID-19 and include epidemiological considerations in the designs of internal spaces in residential houses/apartments and office buildings; and ensure appropriate ventilation in communal spaces in apartment complexes, office buildings and hotels.
- Developers offer clients off-the-plan options for stand-alone houses and apartments that include containment spaces, a structured, compartmentalized layout and appropriate ventilation.
- Transport planners rethink human movement patterns in commuter spaces (subway stations, train station, airports) and all modes of transport.
- Urban planners rethink their approaches to the quantity and quality of public spaces; and most importantly.
- The wider public embraces the need for change.

The time act is now.

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References

1. WHO. Naming the Coronavirus Disease (COVID-19) and the Virus That Causes It. Available online: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/naming-the-coronavirus-disease-(covid-2019)-and-the-virus-that-causes-it (accessed on 10 August 2021).
2. Spreeuwenberg, P.; Kroneman, M.; Paget, J. Reassessing the global mortality burden of the 1918 influenza pandemic. *Am. J. Epidemiol.* **2018**, *187*, 2561–2567. [CrossRef]
3. Ritchie, H.; Ortiz-Ospina, E.; Beltekian, D.; Mathieu, E.; Hasell, J.; Macdonald, B.; Giattino, C.; Appel, C.; Rodés-Guirao, L.; Roser, M. Coronavirus Pandemic (COVID-19). Available online: https://ourworldindata.org/coronavirus (accessed on 10 February 2022).
4. Our World in Data. Coronavirus Pandemic Data Explorer. Available online: https://ourworldindata.org/coronavirus-data-explorer (accessed on 1 June 2021).
5. Moore, J.X.; Gilbert, K.L.; Lively, K.L.; Laurent, C.; Chawla, R.; Li, C.; Johnson, R.; Petcu, R.; Mehra, M.; Spooner, A. Correlates of COVID-19 vaccine hesitancy among a community sample of African Americans living in the Southern United States. *Vaccines* **2021**, *9*, 879. [CrossRef]
6. Riad, A.; Pokorná, A.; Antalová, N.; Krobot, M.; Zviadadze, N.; Serdiuk, I.; Koščík, M.; Klugar, M. Prevalence and drivers of COVID-19 vaccine hesitancy among Czech University students: National cross-sectional study. *Vaccines* **2021**, *9*, 948. [CrossRef]
7. Inayatullah, S. Neither A Black Swan Nor A Zombie Apocalypse: The Futures of a World with the COVID-19 Coronavirus. *J. Futures Stud.* **2020**, *18*. Available online: https://jfsdigital.org/2020/03/18/neither-a-black-swan-nor-a-zombie-apocalypse-the-futures-of-a-world-with-the-covid-19-coronavirus/ (accessed on 1 June 2022).
8. Singh, J.; Pandit, P.; McArthur, A.G.; Banerjee, A.; Mossman, K. Evolutionary trajectory of SARS-CoV-2 and emerging variants. *Virol. J.* **2021**, *18*, 166. [CrossRef]
9. Bonilauri, P.; Rugna, G. Animal Coronaviruses and SARS-CoV-2 in animals, what do we actually know? *Life* **2021**, *11*, 123. [CrossRef]
10. Ye, Z.-W.; Yuan, S.; Yuen, K.-S.; Fung, S.-Y.; Chan, C.-P.; Jin, D.-Y. Zoonotic origins of human coronaviruses. *Int. J. Biol. Sci.* **2020**, *16*, 1686. [CrossRef]
11. Rulli, M.C.; D'Odorico, P.; Galli, N.; Hayman, D.T. Land-use change and the livestock revolution increase the risk of zoonotic coronavirus transmission from rhinolophid bats. *Nat. Food* **2021**, *2*, 409–416. [CrossRef]
12. Ghai, R.R.; Carpenter, A.; Liew, A.Y.; Martin, K.B.; Herring, M.K.; Gerber, S.I.; Hall, A.J.; Sleeman, J.M.; VonDobschuetz, S.; Behravesh, C.B. Animal reservoirs and hosts for emerging alphacoronaviruses and betacoronaviruses. *Emerg. Infect. Dis.* **2021**, *27*, 1015. [CrossRef]
13. Wang, L.-F.; Anderson, D.E.; Mackenzie, J.S.; Merson, M.H. From Hendra to Wuhan: What has been learned in responding to emerging zoonotic viruses. *Lancet* **2020**, *395*, e33–e34. [CrossRef]
14. Peeri, N.C.; Shrestha, N.; Rahman, M.S.; Zaki, R.; Tan, Z.; Bibi, S.; Baghbanzadeh, M.; Aghamohammadi, N.; Zhang, W.; Haque, U. The SARS, MERS and novel coronavirus (COVID-19) epidemics, the newest and biggest global health threats: What lessons have we learned? *Int. J. Epidemiol.* **2020**, *49*, 717–726. [CrossRef]
15. Spennemann, D.H.R. No Entry into New South Wales: COVID-19 and the Historic and Contemporary Trajectories of the Effects of Border Closures on an Australian Cross-Border Community. *Land* **2021**, *10*, 610. [CrossRef]
16. Spennemann, D.H.R. A number's game: Towards a solution to the policing of ringfenced COVID hotspots. *Health Promot. J. Aust.* **2021**, *32*, 352–358. [CrossRef]
17. MHMR. Public Health (COVID-19 Restrictions on Gathering and Movement) Order 2020 (30 March 2020). *N. S. Wales Gov. Gaz.* **2020**, *99*, 1149–1163.
18. Spennemann, D.H.R. COVID face masks: Policy shift results in increased littering. *Sustainability* **2021**, *13*, 9875. [CrossRef]
19. Bian, L.; Gao, Q.; Gao, F.; Wang, Q.; He, Q.; Wu, X.; Mao, Q.; Xu, M.; Liang, Z. Impact of the Delta variant on vaccine efficacy and response strategies. *Expert Rev. Vaccines* **2021**, *20*, 1201–1209. [CrossRef]
20. Nunes-Vaz, R.; Macintyre, C. Observations on the Current Outbreak of the SARS-CoV-2 Delta Variant in Sydney. *Glob. Biosecur.* **2021**, *3*. Available online: https://jglobalbiosecurity.com/articles/10.31646/gbio.121/ (accessed on 1 June 2022).
21. Hazzard, B. *Public Health (COVID-19 Temporary Movement and Gathering Restrictions) Order 2021*; NSW Health & Medical Research: St Leonards, NSW, Australia, 2021.
22. Storen, R.; Corrigan, N. *COVID-19: A Chronology of State and Territory Government Announcements (up until 30 June 2020)*; Parliamentary Library, Commonwealth of Australia: Canberra, Australia, 2020.
23. Chrysanthos, N.; Singhal, P. What Choice Do They Have: Western Sydney's Young Workers Front Up Despite COVID Fears. *syd. Morning Her*. 2021. Available online: https://www.smh.com.au/national/nsw/what-choice-do-they-have-western-sydney-s-young-workers-front-up-despite-covid-fears-20210907-p58pnu.html (accessed on 1 June 2022).
24. Willis, O. COVID-19 Exposes Australia's Stark Health Inequalities—And Threatens to Entrench Them Further. Available online: https://www.abc.net.au/news/health/2021-09-04/covid-19-exposes-australias-stark-health-inequalities/100426178 (accessed on 30 October 2021).
25. Henriques-Gomes, L. Delta Deaths Expose Australia's Great Disadvantage Divide. Experts Say the Spread of Coronavirus among Lower Socioeconomic Communities in NSW and Victoria Was 'Utterly Predictable'. *Guardian*. 2022. Available online: https://www.theguardian.com/australia-news/datablog/2021/oct/12/delta-deaths-expose-australias-great-disadvantage-divide (accessed on 1 June 2022).

26. Hu, M.; Roberts, J.D.; Azevedo, G.P.; Milner, D. The role of built and social environmental factors in COVID-19 transmission: A look at America's capital city. *Sustain. Cities Soc.* **2021**, *65*, 102580. [CrossRef]
27. Li, B.; Peng, Y.; He, H.; Wang, M.; Feng, T. Built environment and early infection of COVID-19 in urban districts: A case study of Huangzhou. *Sustain. Cities Soc.* **2021**, *66*, 102685. [CrossRef]
28. Gupta, S.; Kumar Patel, K.; Sivaraman, S.; Mangal, A. Global epidemiology of first 90 days into COVID-19 pandemic: Disease incidence, prevalence, case fatality rate and their association with population density, urbanisation and elderly population. *J. Health Manag.* **2020**, *22*, 117–128. [CrossRef]
29. Mansour, S.; Al Kindi, A.; Al-Said, A.; Al-Said, A.; Atkinson, P. Sociodemographic determinants of COVID-19 incidence rates in Oman: Geospatial modelling using multiscale geographically weighted regression (MGWR). *Sustain. Cities Soc.* **2021**, *65*, 102627. [CrossRef]
30. Archer, J. *The Great Australian Dream. The History of the Australian House*; Angus and Robertson: Sydney, Australia, 1987.
31. Spennemann, D.H.R. Residential Architecture in a post-pandemic world: Implications of COVID-19 for new construction and for adapting heritage buildings. *J. Green Build.* **2021**, *16*, 199–215. [CrossRef]
32. Chu, V.T.; Yousaf, A.R.; Chang, K.; Schwartz, N.G.; McDaniel, C.J.; Lee, S.H.; Szablewski, C.M.; Brown, M.; Drenzek, C.L.; Dirlikov, E. Household transmission of SARS-CoV-2 from children and adolescents. *N. Engl. J. Med.* **2021**, *385*, 954–956. [CrossRef]
33. Bi, Q.; Lessler, J.; Eckerle, I.; Lauer, S.A.; Kaiser, L.; Vuilleumier, N.; Cummings, D.A.; Flahault, A.; Petrovic, D.; Guessous, I. Insights into household transmission of SARS-CoV-2 from a population-based serological survey. *Nat. Commun.* **2021**, *12*, 1–8. [CrossRef]
34. Laumbach, R.J.; Mainelis, G.; Black, K.G.; Myers, N.T.; Ohman-Strickland, P.; Alimokhtari, S.; Hastings, S.; Legard, A.; De Resende, A.; Calderón, L. Presence of SARS-CoV-2 aerosol in residences of adults with COVID-19. *Ann. Am. Thorac. Soc.* **2022**, *19*, 338–341. [CrossRef]
35. Park, S.Y.; Kim, Y.-M.; Yi, S.; Lee, S.; Na, B.-J.; Kim, C.B.; Kim, J.-i.; Kim, H.S.; Kim, Y.B.; Park, Y.; et al. Coronavirus Disease Outbreak in Call Center, South Korea. *Emerg. Infect. Dis. J.* **2020**, *26*, 1666–1670. [CrossRef]
36. Teknomo, K.; Gerilla, G. Fuzzy Perceptional Spacing for Intelligent Multi Agent Pedestrian Simulation. In Proceedings of the International Symposium of Lowland Technology, Saga, Japan, 14–16 September 2006; pp. 14–16.
37. Bapir, S.Y.; Kareem, S.M. COVID-19 and Functionality: By Providing Social Distancing of Indoor Common Spaces in Residential Building. *J. Stud. Sci. Eng.* **2021**, *1*, 36–45. [CrossRef]
38. Douglas, M.; Katikireddi, S.V.; Taulbut, M.; McKee, M.; McCartney, G. Mitigating the wider health effects of COVID-19 pandemic response. *BMJ* **2020**, *369*, m1557. [CrossRef]
39. Grant, R.; Gorman-Murray, A.; Briohny Walker, B. The Spatial Impacts of COVID-19 restrictions on LGBTIQ wellbeing, visibility, and belonging in Tasmania, Australia. *J. Homosex.* **2021**, *68*, 647–662. [CrossRef]
40. Bil, J.S.; Buława, B.; Świerzawski, J. Mental Health and the City in the Post-COVID-19 Era. *Sustainability* **2021**, *13*, 7533. [CrossRef]
41. Pouso, S.; Borja, Á.; Fleming, L.E.; Gómez-Baggethun, E.; White, M.P.; Uyarra, M.C. Contact with blue-green spaces during the COVID-19 pandemic lockdown beneficial for mental health. *Sci. Total Environ.* **2021**, *756*, 143984. [CrossRef]
42. Heo, S.; Desai, M.U.; Lowe, S.R.; Bell, M.L. Impact of Changed Use of Greenspace during COVID-19 Pandemic on Depression and Anxiety. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5842. [CrossRef]
43. Ettman, C.K.; Abdalla, S.M.; Cohen, G.H.; Sampson, L.; Vivier, P.M.; Galea, S. Prevalence of Depression Symptoms in US Adults Before and During the COVID-19 Pandemic. *JAMA Netw. Open* **2020**, *3*, e2019686. [CrossRef]
44. Geary, R.S.; Wheeler, B.; Lovell, R.; Jepson, R.; Hunter, R.; Rodgers, S. A call to action: Improving urban green spaces to reduce health inequalities exacerbated by COVID-19. *Prev. Med.* **2021**, *145*, 106425. [CrossRef]
45. Alizadehtazi, B.; Tangtrakul, K.; Woerdeman, S.; Gussenhoven, A.; Mostafavi, N.; Montalto, F.A. Urban Park Usage During the COVID-19 Pandemic. *J. Extrem. Events* **2020**, *7*, 2150008. [CrossRef]
46. Uchiyama, Y.; Kohsaka, R. Access and use of green areas during the COVID-19 pandemic: Green infrastructure management in the "new normal". *Sustainability* **2020**, *12*, 9842. [CrossRef]
47. Scott, R.P. Shared streets, park closures and environmental justice during a pandemic emergency in Denver, Colorado. *J. Transp. Health* **2021**, *21*, 101075. [CrossRef]
48. Kleinschroth, F.; Kowarik, I. COVID-19 crisis demonstrates the urgent need for urban greenspaces. *Front. Ecol. Environ.* **2020**, *18*, 318. [CrossRef]
49. WHO. Coronavirus Disease (COVID-19) Advice for the Public. Available online: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public (accessed on 1 September 2021).
50. Qian, M.; Jiang, J. COVID-19 and social distancing. *J. Public Health* **2020**, *30*, 259–261. [CrossRef]
51. Pan, J.; Bardhan, R.; Jin, Y. Spatial distributive effects of public green space and COVID-19 infection in London. *Urban For. Urban Green.* **2021**, *62*, 127182. [CrossRef]
52. Kim, E.A. Social Distancing and Public Health Guidelines at Workplaces in Korea: Responses to COVID-19. *Saf. Health Work.* **2020**, *11*, 275–283. [CrossRef] [PubMed]
53. Hazzard, B. *Public Health (COVID-19 Gatherings) Order 2020*; NSW Health & Medical Research: St Leonards, NSW, Australia, 2020.
54. Abdul Nasir, N.A.B.; Hassan, A.S.; Khozaei, F.; Abdul Nasir, M.H.B. Investigation of spatial configuration management on social distancing of recreational clubhouse for COVID-19 in Penang, Malaysia. *Int. J. Build. Pathol. Adapt.* **2021**, *39*, 782–810. [CrossRef]

55. Hussein, M.; Al-Ayash, A.A.; Al-Mughrabi, N.; Karablieh, M.A. Privacy Zones Investigation of Human Needs in Residential Spaces During COVID-19 (Jordan & Bahrein as a Case Study). *Des. Eng.* **2021**, *5*, 1828–1840.
56. Spennemann, D.H.R. *Collecting COVID-19 Ephemera: A Photographic Documentation of Examples from Regional Australia*; Institute for Land, Water and Society, Charles Sturt University: Albury, NSW, Australia, 2021.
57. Reardon, T.; Heiman, A.; Lu, L.; Nuthalapati, C.S.; Vos, R.; Zilberman, D. "Pivoting" by food industry firms to cope with COVID-19 in developing regions: E-commerce and "copivoting" delivery intermediaries. *Agric. Econ.* **2021**, *52*, 459–475. [CrossRef]
58. Botelho, L.V.; Cardoso, L.d.O.; Canella, D.S. COVID-19 and the digital food environment in Brazil: Reflections on the pandemic's influence on the use of food delivery apps. *Cad. Saúde Pública* **2020**, *36*, e00148020. [CrossRef] [PubMed]
59. Hussain, R.; Dawoud, D.M. Drive-thru pharmacy services: A way forward to combat COVID-19 pandemic. *Res. Soc. Adm. Pharm.* **2021**, *17*, 1920–1924. [CrossRef] [PubMed]
60. Dannenberg, P.; Fuchs, M.; Riedler, T.; Wiedemann, C. Digital transition by COVID-19 pandemic? The German food online retail. *Tijdschr. Voor Econ. En Soc. Geogr.* **2020**, *111*, 543–560. [CrossRef]
61. Mohamad, A.H.; Hamzah, A.A.; Ramli, R.; Fathullah, M. E-Commerce Beyond the Pandemic Coronavirus: Click and Collect Food Ordering. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *864*, 012049. [CrossRef]
62. Attorney-General. Disability (Access to Premises—Buildings) Standards 2010. *Fed. Regist. Legis.* **2010**, *F2010L00668*, 1–54.
63. Handelsverband Deutschland. *Qualitätszeichen Generationenfreundliches Einkaufen. Prüferhandbuch und Technisches Verfahren*; Handelsverband Deutschland: Berlin, Germany, 2013.
64. Architectural and Transportation Barriers Compliance Board. Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities; Architectural Barriers Act (ABA) Accessibility Guidelines. Rule by the Architectural and Transportation Barriers Compliance Board on 07/23/2004 (69 FR 44083). *Fed. Regist.* **2004**, *69*, 44083–44455.
65. Royal Borough of Kensington and Chelsea. Planning Policy Consultations.Access Supplementary Planning Document. Available online: https://planningconsult.rbkc.gov.uk/consult.ti/access.spd.2009/viewCompoundDoc?docid=1247860&partid=1267028 (accessed on 15 October 2021).
66. Pombal, R.; Hosegood, I.; Powell, D. Risk of COVID-19 During Air Travel. *JAMA* **2020**, *324*, 1798. [CrossRef]
67. Shakibaei, S.; de Jong, G.C.; Alpkökin, P.; Rashidi, T.H. Impact of the COVID-19 pandemic on travel behavior in Istanbul: A panel data analysis. *Sustain. Cities Soc.* **2021**, *65*, 102619. [CrossRef]
68. Zhang, N.; Jia, W.; Wang, P.; Dung, C.-H.; Zhao, P.; Leung, K.; Su, B.; Cheng, R.; Li, Y. Changes in local travel behaviour before and during the COVID-19 pandemic in Hong Kong. *Cities* **2021**, *112*, 103139. [CrossRef]
69. Bushwick, S.; Lewis, T.; Montañez, A. Evaluating COVID Risk on Planes, Trains and Automobiles. *Sci. Am.* **2020**, *19*, 2020.
70. Beck, M.J.; Hensher, D.A. Insights into the impact of COVID-19 on household travel and activities in Australia—The early days of easing restrictions. *Transp. Policy* **2020**, *99*, 95–119. [CrossRef]
71. Politis, I.; Georgiadis, G.; Papadopoulos, E.; Fyrogenis, I.; Nikolaidou, A.; Kopsacheilis, A.; Sdoukopoulos, A.; Verani, E. COVID-19 lockdown measures and travel behavior: The case of Thessaloniki, Greece. *Transp. Res. Interdiscip. Perspect.* **2021**, *10*, 100345. [CrossRef]
72. Dyer, O. COVID-19: Australian outbreak surges as New Zealand sees first domestic cases in six months. *BMJ Br. Med. J.* **2021**, *374*, 2050. [CrossRef]
73. Stobart, A.; Duckett, S. Australia's Response to COVID-19. *Health Econ. Policy Law* **2021**, *17*, 95–106. [CrossRef]
74. Department of Health. *National Review of Hotel Quarantine. A Review of Quarantine Systems and Processes in All States and Territories Except Victoria*; Department of Health, Commonwealth of Australia: Canberra, Australia, 2020.
75. Choi, M.; Choi, Y. Employee perceptions of hotel CSR activities during the COVID-19 pandemic. *Int. J. Contemp. Hosp. Manag.* **2021**, *33*, 3355–3378. [CrossRef]
76. Goh, E.; Baum, T. Job perceptions of Generation Z hotel employees towards working in COVID-19 quarantine hotels: The role of meaningful work. *Int. J. Contemp. Hosp. Manag.* **2021**, *33*, 1688–1710. [CrossRef]
77. Ouakrim, D.A.; Katar, A.; Blakely, T. Hotel Quarantine Causes 1 Outbreak for Every 204 Infected Travellers. It's Far from 'Fit for Purpose. *Conversation*. 2021. Available online: https://theconversation.com/hotel-quarantine-causes-1-outbreak-for-every-204-infected-travellers-its-far-from-fit-for-purpose-161815 (accessed on 1 June 2022).
78. Grout, L.M.; Katar, A.; Ouakrim, D.A.; Summers, J.A.; Kvalsvig, A.; Baker, M.G.; Blakely, T.; Wilson, N. Estimating the Failure Risk of Hotel-based Quarantine for Preventing COVID-19 Outbreaks in Australia and New Zealand. *medRxiv* **2021**. medRxiv:10.1101/2021.02.17.21251946. Available online: https://www.medrxiv.org/content/10.1101/2021.02.17.21251946v1 (accessed on 1 June 2022).
79. Fadaei, A. Ventilation systems and COVID-19 spread: Evidence from a systematic review study. *Eur. J. Sustain. Dev. Res.* **2021**, *5*, em0157. [CrossRef]
80. Berry, G.; Parsons, A.; Morgan, M.; Rickert, J.; Cho, H. A review of methods to reduce the probability of the airborne spread of COVID-19 in ventilation systems and enclosed spaces. *Environ. Res.* **2021**, *203*, 111765. [CrossRef]
81. Li, C.; Tang, H. Study on ventilation rates and assessment of infection risks of COVID-19 in an outpatient building. *J. Build. Eng.* **2021**, *42*, 103090. [CrossRef]
82. Porter, P.F.G. Modern Collective Housing of Modernity In Times of COVID-19. Contributions of the Housing Paradigm. *Arquit. Sur.* **2021**, *39*, 28–43. [CrossRef]

83. Martin, J.; Klapsa, D.; Wilton, T.; Zambon, M.; Bentley, E.; Bujaki, E.; Fritzsche, M.; Mate, R.; Majumdar, M. Tracking SARS-CoV-2 in sewage: Evidence of changes in virus variant predominance during COVID-19 pandemic. *Viruses* **2020**, *12*, 1144. [CrossRef]
84. Santiso-Bellón, C.; Randazzo, W.; Pérez-Cataluña, A.; Vila-Vicent, S.; Gozalbo-Rovira, R.; Muñoz, C.; Buesa, J.; Sanchez, G.; Rodríguez Díaz, J. Epidemiological surveillance of norovirus and rotavirus in sewage (2016–2017) in Valencia (Spain). *Microorganisms* **2020**, *8*, 458. [CrossRef]
85. Panchal, D.; Prakash, O.; Bobde, P.; Pal, S. SARS-CoV-2: Sewage surveillance as an early warning system and challenges in developing countries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 22221–22240. [CrossRef]
86. Neuwirth, L.S.; Jović, S.; Mukherji, B.R. Reimagining higher education during and post-COVID-19: Challenges and opportunities. *J. Adult Contin. Educ.* **2020**, *27*, 141–156. [CrossRef]
87. Cone, L.; Brøgger, K.; Berghmans, M.; Decuypere, M.; Förschler, A.; Grimaldi, E.; Hartong, S.; Hillman, T.; Ideland, M.; Landri, P.; et al. Pandemic Acceleration: COVID-19 and the emergency digitalization of European education. *Eur. Educ. Res. J.* **2021**. Available online: https://journals.sagepub.com/doi/abs/10.1177/14749041211041793 (accessed on 1 June 2022). [CrossRef]
88. Skulmowski, A.; Rey, G.D. COVID-19 as an accelerator for digitalization at a German university: Establishing hybrid campuses in times of crisis. *Hum. Behav. Emerg. Technol.* **2020**, *2*, 212–216. [CrossRef]
89. Hurria, C. The Future of the Higher Education Sector in Australia. *J. High. Educ. Theory Pract.* **2021**, *21*, 162–174.
90. Noehrer, L.; Gilmore, A.; Jay, C.; Yehudi, Y. The impact of COVID-19 on digital data practices in museums and art galleries in the UK and the US. *Humanit. Soc. Sci. Commun.* **2021**, *8*, 236. [CrossRef]
91. Cobley, J.; Gaimster, D.; So, S.; Gorbey, K.; Arnold, K.; Poulot, D.; Soares, B.B.; Morse, N.; Osorio Sunnucks, L.; Martínez Milantchí, M.d.l.M.; et al. Museums in the Pandemic: A Survey of Responses on the Current Crisis. *Mus. Worlds* **2020**, *8*, 111–134. [CrossRef]
92. Hanzlík, J.; Mazierska, E. Eastern European film festivals: Streaming through the COVID-19 pandemic. *Stud. East. Eur. Cine.* **2021**, *13*, 1–18. [CrossRef]
93. Hoang, U.; Sharma, K.; Russell, P.; Bergonzi-King, L.; Kapoor, N.; Rae, M.; Seminog, O. Reflections on running an International Public Health Film Competition during the COVID-19 pandemic and implications for future film festivals. *J. Commun. Healthc.* **2021**, *14*, 8–11. [CrossRef]
94. Parker, M.; Spennemann, D.H.R. Stille Nacht: COVID and the ghost of Christmas 2020. *Heritage* **2021**, *4*, 3081–3097. [CrossRef]
95. Kramer, A.; Kramer, K.Z. The potential impact of the COVID-19 pandemic on occupational status, work from home, and occupational mobility. *J. Vocat. Behav.* **2020**, *119*, 103442. [CrossRef]
96. Savić, D. COVID-19 and work from home: Digital transformation of the workforce. *Grey J. (TGJ)* **2020**, *16*, 101–104.
97. Nagel, L. The influence of the COVID-19 pandemic on the digital transformation of work. *Int. J. Sociol. Soc. Policy* **2020**, *40*, 861–875. [CrossRef]
98. Grashuis, J.; Skevas, T.; Segovia, M.S. Grocery shopping preferences during the COVID-19 pandemic. *Sustainability* **2020**, *12*, 5369. [CrossRef]
99. Alaimo, L.S.; Fiore, M.; Galati, A. How the COVID-19 pandemic is changing online food shopping human behaviour in Italy. *Sustainability* **2020**, *12*, 9594. [CrossRef]
100. Koch, J.; Frommeyer, B.; Schewe, G. Online shopping motives during the COVID-19 pandemic—lessons from the crisis. *Sustainability* **2020**, *12*, 10247. [CrossRef]
101. De Smet, A.; Dowling, B.; Mysore, M.; Reich, A. It's Time for Leaders to Get Real about Hybrid. *McKinsey Quarterly* **2021**. Available online: https://www.brianheger.com/its-time-for-leaders-to-get-real-about-hybrid-mckinsey-quarterly/ (accessed on 1 June 2022).
102. Beno, M.; Hvorecky, J. Data on an Austrian Company's Productivity in the Pre-COVID-19 Era, During the Lockdown and After Its Easing: To Work Remotely or Not? *Front. Commun.* **2021**, *6*, 46. [CrossRef]
103. Blake, N. COVID-19 and the economic implications for office occupiers. *Corp. Real Estate J.* **2021**, *10*, 310–321.
104. Kaklauskas, A.; Lepkova, N.; Raslanas, S.; Vetloviene, I.; Milevicius, V.; Sepliakov, J. COVID-19 and Green Housing: A Review of Relevant Literature. *Energies* **2021**, *14*, 2072. [CrossRef]
105. Kadhim, I.J.; Ubaid, W.J. Perception Of Architectural Output: The Presence Of Architecture In The Presence Of a Pandemic. *IOP Conf. Ser. Mater. Sci. Eng.* **2021**, *1067*, 012025. [CrossRef]
106. Megahed, N.A.; Ghoneim, E.M. Indoor Air Quality: Rethinking rules of building design strategies in post-pandemic architecture. *Environ. Res.* **2021**, *193*, 110471. [CrossRef]
107. Bhagat, R.K.; Davies Wykes, M.S.; Dalziel, S.B.; Linden, P.F. Effects of ventilation on the indoor spread of COVID-19. *J. Fluid Mech.* **2020**, *903*, F1. [CrossRef]
108. Gorbunov, B. Aerosol particles generated by coughing and sneezing of a SARS-CoV-2 (COVID-19) host travel over 30 m distance. *Aerosol Air Qual. Res.* **2021**, *21*, 200468. [CrossRef]
109. Pan, J.; Harb, C.; Leng, W.; Marr, L.C. Inward and outward effectiveness of cloth masks, a surgical mask, and a face shield. *Aerosol Sci. Technol.* **2021**, *55*, 718–733. [CrossRef]
110. Kohanski, M.A.; Lo, L.J.; Waring, M.S. Review of indoor aerosol generation, transport, and control in the context of COVID-19. *Int. Forum Allergy Rhinol.* **2020**, *10*, 1173–1179. [CrossRef]
111. Feng, Y.; Marchal, T.; Sperry, T.; Yi, H. Influence of wind and relative humidity on the social distancing effectiveness to prevent COVID-19 airborne transmission: A numerical study. *J. Aerosol Sci.* **2020**, *147*, 105585. [CrossRef]

112. Spennemann, D.H.R. Preparing for COVID-2x: Urban planning needs to regard urological wastewater as an invaluable communal public health asset and not as a burden. *Urban Des.* **2021**, *5*, 75. [CrossRef]
113. Lipman, J. *Frank Lloyd Wright and the Johnson Wax Buildings*; Dover Publications: Minneola, NY, USA, 2003.
114. Richtel, M. Goodbye Open Plan, Hello Cubicles: What Will Offices Look Like after COVID-19. *The Irish Times*. 2020. Available online: https://www.irishtimes.com/life-and-style/health-family/goodbye-open-plan-hello-cubicles-what-will-offices-look-like-after-covid-19-1.4245483 (accessed on 1 June 2022).
115. Mohezar, S.; Jaafar, N.I.; Akbar, W. *Achieving Quality of Life at Work*; Springer: Singapore, 2021.
116. Kim, J.; De Dear, R. Workspace satisfaction: The privacy-communication trade-off in open-plan offices. *J. Environ. Psychol.* **2013**, *36*, 18–26. [CrossRef]
117. Davis, M.C.; Leach, D.J.; Clegg, C.W. The physical environment of the office: Contemporary and emerging issues. In *International Review of Industrial and Organizational Psychology*; Hodgkinson, G.P., Ford, J.K., Eds.; Wiley: Chichester, UK, 2011; Volume 26, pp. 193–235.
118. Kang, S.; Ou, D.; Mak, C.M. The impact of indoor environmental quality on work productivity in university open-plan research offices. *Build. Environ.* **2017**, *124*, 78–89. [CrossRef]
119. Candido, C.; Gocer, O.; Marzban, S.; Gocer, K.; Thomas, L.; Zhang, F.; Gou, Z.; Mackey, M.; Engelen, L.; Tjondronegoro, D. Occupants' satisfaction and perceived productivity in open-plan offices designed to support activity-based working: Findings from different industry sectors. *J. Corp. Real Estate* **2021**, *23*, 106–129. [CrossRef]
120. Barrett, P.; Davies, F.; Zhang, Y.; Barrett, L. The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. *Build. Environ.* **2015**, *89*, 118–133. [CrossRef]
121. Nicolaï, M.; Grange, C. The Digital Transformation of Retail during the COVID-19 Pandemic: A Comparative Study in Canada, China, and France. In *The Impact of COVID19 On E-Commerce*; Mazaheri, E., Ed.; Proud Pen: London, UK, 2021; pp. 1–18.
122. Page, B.; Trinh, G.; Bogomolova, S. Comparing two supermarket layouts: The effect of a middle aisle on basket size, spend, trip duration and endcap use. *J. Retail. Consum. Serv.* **2019**, *47*, 49–56. [CrossRef]
123. Emmanuel, U.; Osondu, E.D.; Kalu, K.C. Architectural design strategies for infection prevention and control (IPC) in health-care facilities: Towards curbing the spread of COVID-19. *J. Environ. Health Sci. Eng.* **2020**, *18*, 1699–1707. [CrossRef]
124. Spennemann, D.H.R. COVID-19 on the ground: Heritage sites of a pandemic. *Heritage* **2021**, *3*, 121. [CrossRef]
125. Larcher, F.; Pomatto, E.; Battisti, L.; Gullino, P.; Devecchi, M. Perceptions of Urban Green Areas during the Social Distancing Period for COVID-19 Containment in Italy. *Horticulturae* **2021**, *7*, 55. [CrossRef]
126. Xie, J.; Luo, S.; Furuya, K.; Sun, D. Urban Parks as Green Buffers During the COVID-19 Pandemic. *Sustainability* **2020**, *12*, 6751. [CrossRef]
127. Dushkova, D.; Ignatieva, M.; Hughes, M.; Konstantinova, A.; Vasenev, V.; Dovletyarova, E. Human dimensions of urban blue and green infrastructure during a pandemic. Case study of Moscow (Russia) and Perth (Australia). *Sustainability* **2021**, *13*, 4148. [CrossRef]
128. Spennemann, D.H.R. Exercising under COVID-2x: Conceptualizing future green spaces in Australia's neighborhoods. *Urban Des.* **2021**, *5*, 93. [CrossRef]
129. Burgos, R.M.; Badowski, M.E.; Drwiega, E.; Ghassemi, S.; Griffith, N.; Herald, F.; Johnson, M.; Smith, R.O.; Michienzi, S.M. The race to a COVID-19 vaccine: Opportunities and challenges in development and distribution. *Drugs Context* **2021**, *10*, 7889064. [CrossRef]
130. Bodas, M.; Peleg, K. Pandemic Fatigue: The Effects Of The COVID-19 Crisis On Public Trust And Compliance With Regulations In Israel: The study examines the effects of the COVID-19 crisis on public trust and compliance with regulations in Israel. *Health Aff.* **2021**, *40*, 1225–1233. [CrossRef]
131. Petersen, M.B.; Rasmussen, M.S.; Lindholt, M.F.; Jørgensen, F.J. Pandemic Fatigue and Populism: The Development of Pandemic Fatigue during the COVID-19 Pandemic and How It Fuels Political Discontent across Eight Western Democracies. *PsyArxiv* **2021**. PsyArxiv:10.31234/osf.io/y6wm4. Available online: https://psyarxiv.com/y6wm4/ (accessed on 1 June 2022).