Chapter 8
Look Ahead

This chapter synthesizes the preceding chapters to derive a final framework that integrates the healthy and smart building practices. The benefits and future potential of this integrated approach are outlined and emphasized.

8.1 Overview

The United Nations estimates that 2007 was the year that, for the first time in human history, more people lived in urban rather than rural areas [1]. In 2018, more than four billion people lived in urban areas globally, and it is projected that by 2050, 68% of the world’s population will live in densely populated built environments, that is, cities [1]. The built environment plays an important role in public health through disease and contamination prevention of chronic and infectious disease. The urbanization trend and worldwide travel have increased the risk of epidemic outbreaks. This book was written as the COVID-19 virus posed a major threat to humanity and while the world was still searching for cures. The high population densities, low herd immunities, and increased mobility of people lead to broader spread of diseases such as COVID-19 within built environments [2]. As explained in previous chapters, the impact of built environments on public health can be direct—for example, changing the indoor environmental quality can induce a variety of “sick building” syndromes. The impact can be indirect as well through influencing behaviors associated with health conditions. When looking into the future for ways in which built environments can help improve public health, three characteristics stand out regarding the development of smart technology: small size, adaptability, and affordability.
8.2 Smart Physical Technologies: Small and Adaptable

As outlined in Chap. 2, the threat of infectious diseases has directly spurred changes in urban planning and architectural design since the mid-nineteenth century, especially those stemming from efforts to provide healthy living and working conditions that could help prevent the outbreak and spread of epidemics. In these efforts to prevent infectious disease transmission, especially through reducing the spread of airborne viruses, modern building standards have identified a variety of disease transmission modes and developed control mechanisms. For example, healthcare design standards require 100% fresh air ventilation in buildings to reduce the dissemination of airborne viruses such as influenza. The role of building in preventing disease spread [way in which a building can spread disease was highlighted in the 2003 SARS outbreak in a private residential apartment complex in Hong Kong, where the ventilation system and sanitary plumbing expedited the spread of the virus [3, 4]. Today, a new generation of biosensors can be integrated in smart building control systems to detect viruses, send warning messages to building control systems, and automatically shut down the central mechanical air circulation system to prevent further virus transmission. Some promising smart sensors include electrochemical, piezoelectric, and optical biosensors [5]. These sensors are small and adaptable and have become more affordable in recent years.

In addition to smart sensors, smart materials can play important roles in making buildings healthy. Besides viruses, toxic pollutants generated from building materials can cause various neurological, cognitive, and behavior problems [6]. More stringent building material requirements can prevent such pollution. Furthermore, incorporating smart building material designs at the nanoscale can turn buildings into pollutant cleaners instead of generators. For example, the Palazzo Italia at Expo 2015 in Milan and the Hospital General Doctor Manuel Gea Gonzalez in Mexico City used bio-dynamic concrete [7] to develop a “living façade” system that breaks down pollutants such as sulfur oxides, soot particles, and nitrogen oxides. The latter are a major component of smog. The bio-dynamic concrete comprises conventional cement mixed with titanium dioxide. The titanium dioxide functions as a catalyst to generate a catalytic chemical reaction when exposed to sunlight. The porous concrete façade allows air to pass through while simultaneously capturing nitrogen particles. The collected nitrogen particles are then washed off by rain. According to the bio-dynamic concrete designers, the nitrogen particles captured by one of the building façade in Mexico City can offset the effects of air pollution from one thousand cars [7]. Concrete is a very versatile yet fundamental building material. The future application of such technology could be widespread. Besides improving conventional concrete at the molecular scale as with bio-dynamic concrete, other smart building materials and systems are under development. The data collected from their pilot projects will shape the way in which smart technologies can change our approach to pollution mitigation.
8.3 Smart Design Technologies: Affordable

Fortunately, not all smart technologies are costly. Many sustainable design technologies create no additional costs as they provide health benefits to people. For example, windows that open are essential for natural ventilation. Using natural ventilation can decrease the need for cooling in the summer and increase air circulation to prevent air stagnation, which is a crucial defense against airborne viruses. Research has shown that, while viral particles are too small to be blocked by air filters in mechanical systems, natural ventilation strategies can dilute the concentration of virus particles indoors by bringing in fresh air [8]. Also, in high humidity environments, virus-bearing water droplets get bigger, settle out of the air more quickly, and thus don’t travel as far [8]. This characteristic may be why the flu season often coincides with winter, which is a low-humidity season [9, 10]. Therefore, sustainable design strategies that provide comfortable indoor environments with appropriate humidity ranges will help fight virus transmission. Such smart design strategies normally do not involve additional costs. They only need to be integrated in projects right from the start.

In the previous chapters, we explained built environment design strategies—for instance, a well-designed and maintained street segment—correlate with building residents being more active physically and experiencing lower mental stress. In contrast, large streetscapes with low detailing and complex building facades are more likely to be perceived as stressful [11]. Again, changing design strategies to avoid this stress-inducing effect has no associated cost and therefore is affordable for everyone. However, achieving such change requires an integrated approach from urban planners, transportation engineers, policymakers, and architecture designers, along with an in-depth understanding of how built environments can impact public health.

8.4 Emerging Issues: Epidemic and Aging

Currently, two major public health threats exist that can be substantially influenced by built environments: epidemics and aging. Built environments have significant impacts on disease transmission and on human behavior related to disease spread. The spread of a virus can be directly influenced by built environment properties such as spatial configurations within buildings and how people’s mobility is affected by the city’s spatial configuration [11]. People’s daily movement patterns in densely populated urban areas are highly predictable [11], and current city-level epidemiological models can integrate commuting information, geospatial data, and infection dynamics and spreading characteristics to help cities develop preventive strategies [12–14]. That said, the spatial configuration of physical built environments is not being taken into consideration in developing such strategies [11]. Bridging the gap between urban planning and public health prevention planning can lead to different
types of urban spatial planning. Perhaps school buildings should be located adjacent to public transportation hubs. Perhaps people should work in places close to home to reduce their “mobility” and hence reduce the opportunity for virus transmission. And perhaps large suburban shopping malls are an “unhealthy” building type that facilitates cross-contamination. These are questions planners, urban designers, and public health researchers should collectively investigate and answer.

Aging is another growing public health concern. Chronic disease affects the older population disproportionately. In the United States, the proportion of the population aged ≥65 years, which was 12.4% in 2000, is projected to increase to 19.6% in 2030. Persons aged ≥80 years, who numbered 9.3 million in 2000, are expected to increase to 19.5 million in 2030 [15]. In response, over the past decade, a variety of age and disability friendly smart building systems have been developed. The three case projects introduced in Chap. 7 demonstrate a wide range of available smart systems and technologies. The common theme of those technologies is to make “aging in place” and “living independently” possible and affordable. The guiding principle of smart design is to make built environments and architectural spaces “smart ready” so they can accommodate ongoing technological advancement. In other words, smart buildings and smart built environments should not be fixed sets of equipment, devices, and spaces. Instead, they should be flexible and adaptable to future changes.

8.5 Looking Ahead: Ways the Built Environment Will Change Post-pandemic

Technology alone will not make a healthy built environment. If other core elements of built environments, such as public health and public service, are not integrated in design and planning, the efforts to construct technologically advanced smart buildings and cities that promote and preserve health will fail. The built environment must change profoundly, especially after pandemics like COVID-19. Public health concerns demand built environments with smart infrastructures and smart buildings that work together to set up a holistic and integrated approach. At the urban scale, the public transit pattern in particular will need to change. Crowded public transit hubs clearly pose risks for rapid virus transmission. According to Milan’s mayor, Beppe Sala, the city plans to reduce its metro system’s capacity by up to 30% of its pre-pandemic activities [16]. In The Netherlands, longer, more spacious trains will be put in use to give passengers more room to spread out. Berlin is opening up more lanes for cyclists. In Britain, bus passengers are entering through the middle or rear doors to reduce the virus risks for drivers [17]. Along with this kind of smart planning, smart technologies are being used for contact tracing, especially in the Asian countries hit earliest by the novel coronavirus and with the highest population densities. Tech companies such as Apple and Google have announced plans to turn phones into opt-in COVID-19 tracking machines, which will make it easier for
health officials to identify and alert people if they have been exposed to the virus while preserving their privacy [18].

At the building scale, touchless smart sensor technologies could become dominant post-pandemic. We already have touchless faucets, automatic doors, and smart thermostats, among other innovations. Smart sensors will be added in densely populated building types such as apartments and schools to monitor the environment and reduce unnecessary contact. Also, during the current lockdown, the empty commercial buildings worldwide have wasted energy on unnecessary ventilation and heating. Many empty buildings continue to run central plant equipment and have not adjusted their operating time schedules in many cases due to the inflexibility of the building management systems. Smart building technologies can dramatically curb energy waste by monitoring and managing building operations remotely [19].

Eventually, the world will go back to more in-person contact. Workers need to interact with colleagues to spark ideas. School children need to interact with teachers and other students to develop social skills. For people to feel confident that we can safely go back to normal life, we need to provide clean office environments and public spaces. More importantly, we need to collectively make smart, healthy buildings, and built environments the norm.

In the past few decades, the focus of built environment design and construction has been on energy and resource conservation, and smart technologies have been developed to meet those goals. This focus is understandable in the context of the sustainability movement. But buildings are not only machines for living. They are also shelters to escape to, places to recover. In that sense, they should be environments that can protect and improve people’s physical and mental health. Built environments affect human health at multiple scales, including the urban and building scales. At the urban scale, urban planning and design can impact population-level processes by shifting how close individuals must be to one another and their mobility patterns. At the building scale, the interior layout and spatial structure can affect people’s physical and psychological wellbeing.

Tomorrow’s challenge lies in creating healthy, sustainable, smart built environments with low energy use. Sustainable building should also be healthy building in terms of its responsiveness to occupants’ wellbeing and health [20]. Smart technologies can help achieve such goals. The first step toward a comprehensive guideline for smart, healthy, sustainable building is to gather more empirical data so that the mechanisms of how built environments influence human health can be better understood. There is also an urgent need to create greater public awareness of the health impact of built environments, as well as the availability of smart technologies that can mitigate negative impacts. Overall, the built environment design and construction industry needs to focus primarily on making built environments healthy for living and working. For this to succeed, new players need to be involved, players such as computer science, information, and communication technology (ICT) professionals, to develop and implement smart technologies and solutions. The collaboration of all stakeholders will likely be the key to our succeeding in building healthy, smart built environment over next decade or two.
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