Post-pandemic Urban Planning:
Innovations in Cities and Neighborhoods

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ABSTRACT

Historically, major pandemic outbreaks have often been followed by large-scale transformations of the built environment in pursuit of 'healthier' cities and neighborhoods. The COVID-19 pandemic, which began at the end of 2019, has also triggered a wider discussion about urban density, layout and accessibility to public facilities, and so on. However, long-term factors that influence health outcomes from a post-pandemic perspective remains unclear. To fill this gap, the focus of this doctoral research is to explore new directions in urban planning in the post-pandemic era and to develop a healthy model for neighborhood planning under the guidance. To achieve the goals, this study adopts a combination of quantitative and qualitative analysis to step-by-step address the target issues, including: 1) a systematic literature review on urban planning responses to pandemics, 2) empirical observations based on residential areas in pandemic epicenters, and 3) data modeling for a post-pandemic neighborhood assessment framework. The systematic review indicates that the COVID-19 pandemic has brought urban planning back to the theme of public health, directing it towards more localized and indigenous working models. At the community level, the ongoing impact of COVID-19 has reshaped the planning structure of residential areas due to emerging lifestyle changes such as reduced residents' travel range, expanded online activities, increased demand for natural and outdoor activity spaces, and enhanced willingness to participate in community management. Through empirical observations and data collection in the city of Wuhan, a post-pandemic neighborhood evaluation system covering four dimensions: physical, environmental, demographic, and socioeconomic, has been established to assist government officials and urban planners in quickly identifying vulnerable areas and promoting health equity.

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1. Tu, K., & Reith, A. (2023). Changes in Urban Planning in Response to Pandemics: A Comparative Review from H1N1 to COVID-19 (2009–2022). Sustainability, 15(12), 9770. DOI: https://doi.org/10.3390/SU15129770
2. Tu, K., Reith, A. (2023). The Impact of Post-pandemic Lifestyle on Neighbourhood: Changes from 2020 to 2022 in Wuhan, China. In: Cheshmehzangi, A., Sedrez, M., Zhao, H., Li, T., Heath, T., Dawodu, A. (eds) Resilience vs Pandemics. Urban Sustainability. Springer, Singapore. https://doi.org/10.1007/978-981-99-7996-7_11
3. Tu, K., & Reith, A. (2023). Designing for Health - A Study of Architecturally Oriented Public Space. Pollack Periodica. 18(3), 158-163. DOI: https://doi.org/10.1556/606.2023.00938
4. Tu, K., & Reith, A. (2022). Renewal Strategies of High-density Neighborhood for Encouraging children's active living. UBT International Conference. 15. DOI: https://knowledgecenter.ubt-uni.net/cgi/viewcontent.cgi?article=4221&context=conference
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6. Tu, K., Niu, Y, Reith, A. (2024). Regeneration design of mining brownfield based on Nature-based solutions. Pollack Periodica. (preprint)
7. Tu, K., & Reith, A. (2024). Navigating the Post-Pandemic Era: Priorities for Neighborhood Planning based on COVID-19 Long-term Impacts. (Submitted)

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Chapter 1: Introduction and key Definitions

In 2020, the COVID-19 pandemic unfolded as a crisis of unprecedented proportions, eclipsing the impact of pandemics from the preceding two decades (Johnson et al., 2020). This crisis brought forth a multitude of challenges for society, ranging from strained healthcare resources and food shortages to logistical disruptions, limited public spaces, the proliferation of slum conditions, and profound psychological risks stemming from quarantine measures. Amidst these challenges, urban planning found itself confronted with a series of issues, underscoring the pressing need for innovative approaches.

While there exists a plethora of potential strategies for addressing urban challenges, current initiatives by urban planners exhibit a remarkable uniformity, often adhering closely to existing infrastructure, land structures, and governance models. It is crucial to discern the enduring legacy of the COVID-19 pandemic, identify its lasting and profound impacts, and understand the fundamental paradigms that have been disrupted. Notably, most studies have concentrated on the macro-level dynamics of cities, with fewer delving into the micro-level intricacies of settlements intimately intertwined with the daily activities of their residents.

This chapter provides an outline of the study. It starts with a general context on the importance of the research. After that, it introduces the purposes and main procedures, then concludes with concepts that are relevant to the topic.

1.1 Background to the research

1.1.1 Global rage of infectious diseases

The outbreak of the coronavirus has unfolded into a significant global safety and health crisis. As of 16:15 p.m. Budapest time on November 2, 2023, the World Health Organization (WHO) has reported 233,503,524 confirmed cases of COVID-19, with 4,777,503 deaths globally (WHO). This staggering figure serves not only as a poignant reminder for the reconsideration of urban development, safety, and health but also carries far-reaching implications for global

initiatives. The pandemic has thrust public health hazards into the forefront, emphasizing the intricate interplay between public health events and human survival.

The World Health Organization (WHO) had identified infectious-related diseases as six of the top 10 threats to global health in 2019, underscoring the evolving nature of public health challenges compared to previous concerns related to individual unhealthy behaviors. The pandemic has exerted its influence across various dimensions, as outlined in the Global Disease Assessment Report 2021, which categorizes the impact of the COVID-19 pandemic into four main areas: travel, business activities, work styles, and urban environments.

In terms of travel, the pandemic has resulted in restricted travel and diminished willingness to engage in extensive travel, leading to a sharp decline in travel activities globally (Gössling et al., 2020). Concerning business activities, the widespread adoption of remote work practices, even after a brief slowdown in the pandemic, has contributed to a general reluctance to visit crowded shopping malls, causing economic stagnation, particularly impacting offline stores (Qiu et al., 2020). Regarding work practices, the COVID-19 pandemic has accelerated the development of an information society, with an increasing number of individuals opting for remote work. This shift has nullified the physical constraints of the traditional workplace, potentially reshaping the layout patterns of residences and offices (Sharifi, A., 2019). In the context of the built environment of cities, the pandemic-induced changes in lifestyle preferences, such as an increased emphasis on housing and public space, have given rise to new requirements. This includes the need for improved zoning of residential functions, increased parks and green spaces, and a reevaluation of street design (Sharifi, A., 2019). Technologists advocate for innovative technologies in urban health services to establish redundant capacity for crisis response (Kummitha, 2020).

In summary, the current focus of scholars, experts, and society at large revolves around the challenge of shaping and building cities that are healthy, safe, inclusive, and sustainable in the wake of the COVID-19 pandemic.

1.1.2 Urban planning's focus on public health

The intertwining relationship between urban planning and public health dates back to 1848 when two outbreaks of public health hazards in London prompted contemplation on designing urban environments to prevent the spread of diseases. The Public Health Act of 1848, originating in the United Kingdom, outlined measures such as improving drainage and sewerage, eliminating street litter, and providing clean drinking water, marking the inception of the first urban planning system. Thus, urban planning and public health share a common root and origin.

In subsequent years, influential works like Howard's "Tomorrow's Idyllic City," Corbusier's centralized planning and construction, and Abercrombie's "The Great Big City" all contributed to the intersection of urban planning and public health. In 1842, the Town Health Association was established in Britain, laying the groundwork for the concept of a healthy city. After the World Health Organization (WHO) introduced the idea of "Healthy City," the development of healthy cities became a global movement. This movement gave rise to evaluation systems like "Healthy City Evaluation" and "Healthy Community Evaluation."

While urbanization has progressed, increased attention has been given to the built environment and health, particularly in the realms of chronic disease prevention and the promotion of active lifestyles. However, research on urban planning to mitigate infectious diseases has been limited. The emergence of the COVID-19 pandemic has underscored these gaps. Although the means to reduce or mitigate infectious diseases in urban environments remain unclear, empirical studies indicate that urban spaces characterized by excessive construction density, limited public space, inadequate green space, and a lack of slow-moving systems are not conducive to residents' needs and complicate the management of sudden-onset public health emergencies (Saadat et al., 2020). Urban planning must contemplate how to positively impact population health through optimal spatial layouts and resource allocation.

1.1.3 Rise of neighborhood-level activities

The outbreak of the coronavirus has prompted industries to reconsider strategies for effectively containing the pandemic, with a notable emphasis on implementing physical isolation. Studies have consistently highlighted that, post-outbreak, residents' travel patterns have been constrained spatially and temporally, leading to a concentration of daily leisure activities within the neighborhood (Kraemer et al., 2020). Particularly during the initial stages of the outbreak (January 2020-May 2021), home isolation and travel restrictions played a crucial role in mitigating virus spread. The prolonged period of homebound living has generated new demands among residents for features in their living spaces, such as provisions for online telecommuting and study, larger balconies, and dedicated spaces for in-home disinfection. As the pandemic stabilized (May 2021-April 2023), with declining new cases and the gradual resumption of societal activities, residents' preferences for the built environment evolved, placing a greater emphasis on community logistics facilities, outdoor activity spaces, green parks, and similar amenities (Mishra et al., 2020). The third stage, characterized by the normalization of pandemic prevention and control (May 2023-present), sees residents leveraging their experiences in pandemic coping mechanisms. During this period, there is a distinct preference for completing daily activities, such as walks, conversations, and interactions, within a walkable distance in their immediate vicinity.

The significance of the neighborhood during the pandemic is underscored by residents' inclination to conduct daily leisure activities in proximity to their homes, driven by concerns about infection during long-distance travel. Consequently, the physical environment at the neighborhood scale assumes heightened importance in providing conducive spaces for residents' physical activities. Additionally, the effectiveness of community governance, as the grassroots organizational unit of the city, plays a crucial role in the city's emergency response capacity (Connolly et al., 2020). Countries like the United States, Japan, Australia, and the United Kingdom have established suitable community-level organizations equipped with specialized preventive emergency facilities, facilitating rapid responses to alleviate emergencies. As a result, the study of the neighborhood scale has become a focal point for scholars and government policies.

1.2 Research purposes, processes and questions

The COVID-19 pandemic has brought about significant changes in urban life, and it has highlighted the importance of public health and well-being in urban planning and design. The prime purpose of this research is to explore "How pandemic (COVID-19) AND urban planning's responses to pandemic will ultimately shape our cities and neighborhoods? " To achieve this aim, the study divides the research process into three parts.

- First and foremost, a systematical review of the historical literature of H1N1(2009) and COVID-19(2019) on the pandemics and their documented connections to urban planning is conducted, aiming to identify "What changes have recently taken place in urban planning in response to pandemics?", meantime, seeking to explore which urban planning theories or models were used in response to pandemics and how they evolved through the past decade. The main changes in urban planning in coping with the COVID-19 pandemic and its predecessor are highlighted, identifying whether COVID-19 has upgraded capacities/theories/techniques, which presents future trends. It offers the very foundation for the later steps of the study.

- Next, another PRISMA literature review targeting the neighborhood scale is launched. The considerable time that has elapsed since the outbreak has provided ample opportunity for researchers to make observations. From the beginning of 2020 to the end of 2023, through theoretical and empirical studies, an attempt was made to explore "How does the COVID-19 pandemic influence the neighborhoods? How does neighborhood planning respond? Which of these impacts/responses will work in the long term?" .

- Last, by sorting out the neighborhood-related factors that affect the health of residents, especially in prevention or mitigation of pandemics, an attempt is made to establish an evaluation system for healthy neighborhoods in the post-pandemic era. It also takes four neighborhoods in Wuhan as case studies to assess their health level and compare the differences in between. Finally, the Gonglu neighborhood is used as an example to propose how renewal strategies can improve the health of residents in the post pandemic

context.

1.3 Thesis structure

In this chapter, it has presented an overview of the general research context and the purposes, as well as the main research questions (Figure 1.1). Next, key definitions closely related to the theme of the thesis are specified and described. After that, the research questions that are broken down will then be discussed one by one, corresponding to each of the chapters that follow.

Chapter 2 describes the methodologies as well as the findings of systematic review on changes of urban planning's response to pandemics in the past decade.

Chapter 3 conducts an in-depth review of the specific changes that have brought by COVID-19 at the neighborhood-level, building on the post-pandemic urban context provided in the previous chapter. Both the methodological paths of theoretical and empirical studies are included, as well as the predicted trend results.

Chapter 4 is designated to introduces the approach and results of establishing an integrated assessment framework for post-pandemic neighborhood, supplemented by a presentation of neighborhood renewal strategies to enhance the well-being of residents in the future.

Chapter 5 aims to discuss the findings derived from the analyses conducted in Chapters 2 through 4.

Chapter 6 and chapter 7 address the limitations and conclusions of the thesis, respectively.

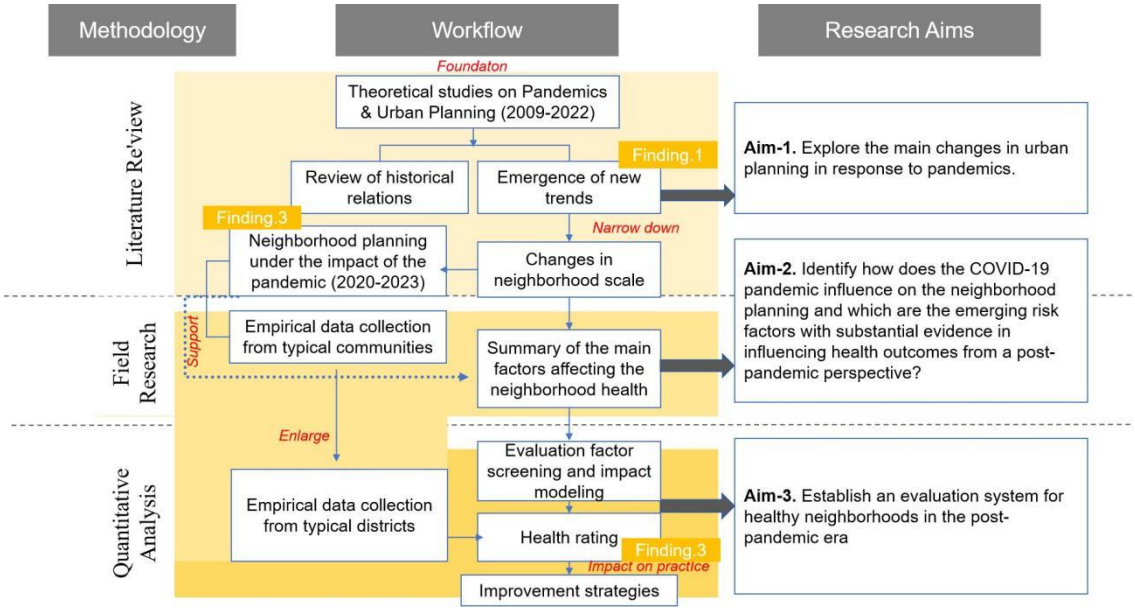

Figure 1.1 Technical route of the thesis.

1.4 Research foundations and related conceptions

1.4.1 Urban planning and public health

The relationship between urban planning and public health goes back a long way. The severe public health crises and their response in history not only led to the establishment of the discipline of public health, but also indirectly contributed to the birth of modern urban planning (Wang, 2020).

Urban planning , public health and city movements

In 1848, the United Kingdom passed the world's first Public Health Law to ameliorate the spread of infectious diseases since the 14th century, which was the first legislation to call on government to set minimum levels of sanitation and housing construction in cities (Gostin et al., 2014). Typhoid and cholera in the 19th century saw the development of sewage and water systems to fight pathogens, ultimately resulting in sanitary advancements (Diana, 2020). Till the 20th century, large number of parks, promenades, squares were built in Europe as the early attempts of providing safer urban space after the so-called Spanish flu (Ian, 2020). It is no exaggeration to say that the infectious disease shaped the modern cities by getting them to supply clean water, remove garbage, amend building codes and strengthen administration

management (Pinheiro et al., 2020).

At the same time, public health crises has contributed to the development of city movements, particularly in the evolution of updated urban theories (Mapar et al., 2020). On the foundation of city movement timeline summarized by He et al., (2020), another timeline of major global public health emergencies and infectious diseases were added by authors (pandemics were particularly marked), see in Fig 1.2 By the overlap of the two, it is quite clear that Garden city, Healthy cities, Eco-city, Sustainability, Green city, Smart city, Resilient cities... thrived on challenges. City movements and urban theories were more active when health crises were more concentrated, such as 1860s-1920s, 1960s-1990s and 2000s-2010s, which overlapped highly on the time axis. In order to alleviate the public health problems caused by the rapid expansion of urban overcrowding, Howard proposed the theory of the Garden city (Howard, 1898), which attempted to improve urban health by limiting the population and organizing green spaces, thus starting the garden city movement, which had a significant impact on the world in the early 20th century. In 1916, New York followed the example of France and Germany and effectively created a healthy urban environment by implementing a zoning system (Hall, 2002). In the middle and late 20th century, under the influence of environmental pollution, social conflicts and the deepening of global trade, the speed and scope of the spread of infectious diseases further increased (Awofeso, 2004), the problem of health inequality intensified (Tomas, 2005) and global public health faced huge challenges (Susser, 1996). Subsequently, theories in urban sociology, ecology, and political economy have been systematically developed, such as the urban diversity advocated by Jacobs in 1961 (Jane, 1992), the resilience theory proposed by Holling in 1973 (Holling, 1973), the health promotion initiated by WHO in 1986 (Wills, 1998), and the concept of green city in 1990 (Lehmann, 2011), etc. With further strengthening of global integration after 2000, new urban theories such as smart city and resilient cities were applied in response to global public health emergencies like Ebola (Kieny, 2014). In general, urban study is in a state of constant evolvement as public health crises occur one after another.

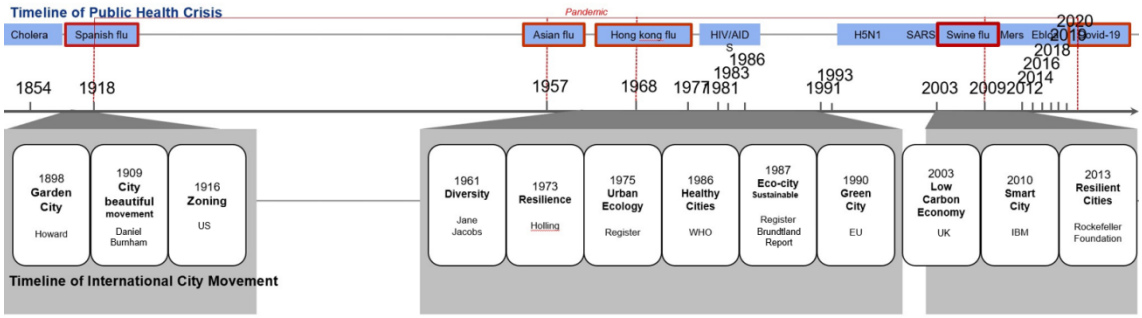

Figure 1.2. Relationship between international city movement and public health crisis (redrawn based on He et al., 2020 [**Hiba! A könyvjelző nem létezik.**])

The dynamic evolutionary relationship between urban planning and public health

Yet when focusing on recent urban planning or urban planning theory in relation to public health, there were three major watersheds. One was in 1920s, public health has shifted the focus of research to individual risk factors (e.g., smoking, diet) and away from urban planning, which focuses on external spatial factors (Jason, 2009). Especially with the breakthrough of "germ theory" in the medical field, the emphasis of public health mainly relied on bacteriological study (Jason, 2009). Much of the research devoted to discovering ways or interventions to eliminate bacteria (in water/milk/food...) in the laboratory, and no longer to the transformation of the built environment in cities. The advent of vaccines in that time also made people believe that pandemics could no longer constitute a primary threat to public health. And the other occurred in 1990s after the World Health Organization (WHO) launched the health promotion that the urban environment again became one of the important elements of health support (Wills, 1998), leading to extensive research on healthy urban planning (Jia et al., 2021). While these studies focused on the prevention and control of chronic diseases and the encouragement of physical activity (NIPH, 2020), with little research on infectious diseases. It was therefore not until 2020s when the coronavirus began to rage, the impact of the infectious disease on cities seemed to expand even more, with far-reaching effects on various countries and regions (Acuto, 2020) that pandemics once again became the very focis of urban planning. Closure of the city, physical isolation, social distance, mask orders,

prevention and control policies that had never been implemented on such a large scale in a century, caused many reflections in urban studies (Bereitschaft & Scheller, 2020), which pointing out that COVID-19 particularly affected cities, as many of its problems were related to urban patterns, environmental quality, or the socioeconomic and health status of populations (Patrick et al., 2022). Excessive construction density, interruption of transportation and logistics, poor information communication, shortage of medical and public services, and uneven spatial distribution of public and green spaces all became huge obstacles in controlling the pandemic (Ibert et al., 2022. As such, cities need to transform their urban planning models and principles to face the pandemic (Batty, 2020).

To sum up, in the light of the above background, The relationship between urban planning and public health is strong and long-standing. It has gone from intervening in health primarily by changing the urban physical environment, to emphasizing chronic diseases and promoting healthy lifestyles, to the current Coronavirus outbreak, which has put a new priority on how cities can prevent and control the future pandemics and other hazards. But whatever the stage, cities have always been built and developed to improve human health and well-being. While each public health crisis poses new challenges to urban planning, it also provides opportunities for the development and innovation of urban planning theories and technical methods. It is foreseeable that new urban planning, design and management strategies that promote public health are being birthed in the near future.

1.4.2 Neighborhood planning and its association with population health

Healthy cities and Healthy communities

A neighborhood is a community, geographically localised within a larger city, town, or rural area, represented by a spatially defined unit, with its own system of functional and social networks（UN-Habitat, 2023).

Neighbourhood-scale interaction with city-wide systems should be linked to ensure design initiatives can bring a maximum impact for both community and the city. In order to ultimately realize the health of cities, it is essential to translate global, national and regional

policies and strategies into concrete project measures for planning and designing interventions at the local, and especially the community level（UN-Habitat, 2023).

Based on this relationship, the origins and development of Healthy neighborhoods are closely related to Healthy cities (Figure 1.3). After the concept of “Healthy cities” was introduced at the Healthy Toronto Conference in 1984, the “Healthy Cities Project” (HCP) was launched by WHO in North America and Europe in 1986 to promote research and development of Healthy Cities. This was followed in 1987 by the European Network of Healthy Cities, a partnership between World Health Organization (WHO) and European countries aimed at building cities around specific themes (WHO, 2015). Among them, the Healthy Community Movement was initiated by Duhl and Hancock, initially with WHO in the lead through the HCP, with the aim of improving the health of individuals and groups in the community, covering social, economic, natural and built environment aspects (Norris, 2000). Research on neighborhood work was in full swing since 1987 when Willian Julius Wilson Investigating the role of neighborhoods ( ), and there had been a gradual increase in the number of studies addressing neighborhood health. By early 1990s, “Healthy Cities” fast became a major global movement for the new public health internationally. While this movement advocates “Local Problems, Local Solutions and Local Resources”, and healthy communities gradually became the object of study for many scholars, government personnel, planners, and other groups with the topics of research had diversified. After more than 30 years of development, the Healthy Communities Movement has now reached more than 3,000 communities in more than 50 countries (Norris, 2000). After the Alliance for Healthy Cities (AFHC) founded in 2003, global cooperation had intensified and a number of cities emerged to share their successes, including LEED-ND (2009), Active Design Guidelines (2011), and Designing a Healthy LA (2013). And a new phase began in 2019 to ensure that the WHO Healthy Cities Network becomes the vehicle for WHO to implement the SDGs at the local level by 2030, i.e. fully integrating health policies into the UN 2030 Agenda (Ashton et al., 2018).

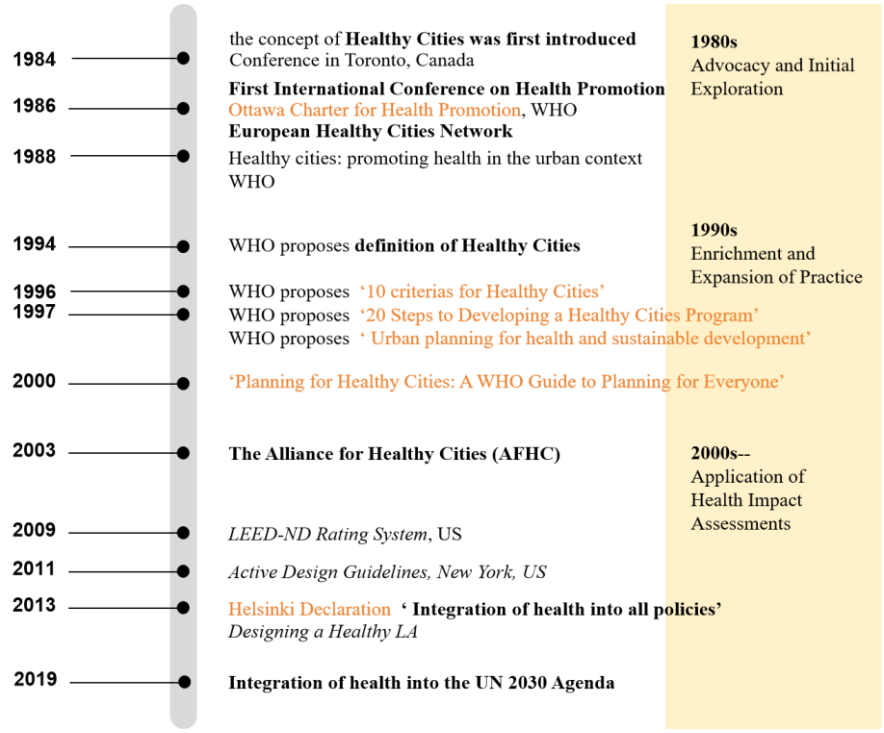

Figure 1.3 Revolution of Healthy cities and communities (Plotted by author)

Concept, domains and main factors affecting healthy neighborhood

The concept of healthy neighborhood combines the meanings of "health" and "neighborhood", thus the "health" is expanded from the individual to the community as a whole; all organizations within the community can work together effectively to improve the quality of life of all residents within the community. However, there is no uniform definition of a healthy neighborhood, the consensus is that its planning and construction is not limited to the field of public health. To ensure a comprehensive and integrated approach to healthy neighborhood planning, it is required to consider a variety of issues, such as social, economic, environmental and so on.

As early as 1948, when WHO was founded, health was defined as a state in which physical, psychological, and social adaptations tend to be intact, and not merely the absence of disease and infirmity (WHO, 1947). Noack (1985) took a systems perspective and viewed human beings as part of interdependent and interacting ecosystems ranging from molecules to ecosystems; proposing that health is a process of maintaining dynamic equilibrium in an

established system, which is the unity of physical health, mental health and social health (individuals balanced in society) (Horst, 1985). According to Hancock and Duhl (1988),‘A healthy city is one that is continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions of life and developing their maximum potential’. Thus for any individual in a community, health is a broad concept that includes overall physical, mental, social and spiritual health (Gunderson, 2000). On the other hand, a healthy community is not entirely a simple collection of healthy individuals; the community as a whole should have various conditions to promote people's health, including socio-cultural, economic, natural, and technological environments, as well as the interaction between individuals and the environment (Horst, 1985). The concept of a healthy community, as proposed by Lee (2000), emphasized a holistic understanding of both health and community, including a broad definition of "health" and a broad definition of "community," and stresses the importance of achieving shared community values, focusing on the quality of life for each individual, advancing pluralistic civic participation and universal community property rights, as well as empowering the use of local assets and resources, and monitoring and evaluating progress and health outcomes (Lee, 2000). Tylor (2000) proposed a seven-point philosophy of healthy communities that includes: communities connect people and resources; community residents need to have or create a strong sense of self and know their community; consciously shape their own future; develop self-leadership at all times; welcome and embrace diversity; the principle of problem solving through ongoing dialog in practice; and communities welcome and create systemic change (Norris, 2000). Tanata Ashby and farr (2012) further stated that a healthy community is one in which all citizens have access to good education, safe and healthy housing, appropriate jobs, transportation, physical activity, nutrition, and good health care (Falk and Carley, 2012) .

In terms of factors affecting the human health, academics have widely used the "health map" model proposed by Barton and Grant (2006), who developed a "circle" model consisting of four dimensions, showing the determinants of health and well-being in neighborhoods including the community, behavioral activities, the built environment, and natural resources

(Figure 1.4). And “Shaping Neighborhoods: For a Network of Healthy Cities in Europe” published by Hugh Barton et al. in 2003, with the third and fourth chapter can be seen as the concentrated results of the Healthy Community Movements mentioned above. The book showed how the basic principles of neighborhood planning can be applied in practice.

Figure 1.4 Health map (Barton & Grant, 2006)

Thus it is because of the complex systems involved in healthy communities that research on healthy communities spans multiple disciplines and fields. Most of them focus mainly on the relationship between places and health. At the physical level, including the impact of green living environment, physical activity space, and community location on residents' health. In terms of green living environment, scholars focus on the impacts of community gardens, urban agriculture, etc. on climate and air quality, residents' stress release, and neighborhood communication; in terms of physical activity spaces, they focus on the impact of physical exercise on health; and community location mainly affects the physical infrastructure that residents need for their daily lives, such as medical services, day-care facilities, and food stores (eating and drinking environments). At the non-physical level, the emphasis is on social roles and social capital, including community policy and management, public participation, etc.

From these results, it is clear that the built environment of a community plays a key role in the health of its residents. And according to the classification of UN-Habitat (2023), main spatial factors affecting healthy neighborhoods include, 1) Land use, 2) Urban form and design, 3) Transport and movement networks, 4) Green, blue and public open space. The combination of these factors affects the health of the population either positively or negatively from the following three pathways, 1) Protect from harm, 2) Promote health, 3) Provide services.

Land use

Table 1.1 The impact of Land use on healthy neighborhood

Planning factors		**keywords**	**Literature**
Land use	Mixture degree	Diversity in land use Dissimilarity indices Percentage of commercial land Percentage of public facilities Number of mixed-use plots, Residential per nonresidential area ratio Economic floor area per total floor area ratio	Hachem-Vermette et al, 2019; Wineman et al, 2014; Stanislav et al, 2019; Zumelzu et al, 2019; Larimian et al, 2020; Asfour & Zourob, 2017; Allen et al, 2018; Pineo et al, 2018; Dawodu et al, 2019; Shirazi et al, 2020.
	Intensity	Built-up density Per capital road area Per capital green land use area Population Density Floor area ratio	Ferwati et al, 2018; Hilley et al, 2020; Moroke et al, 2020; Kamble et al, 2021; Alipour et al, 2021; Larimian et al, 2020; Shirazi et al, 2021; Kameni et al, 2020; Stanislav et al, 2019; Caroleo et al, 2019.

A review of the literature shows that a large number of studies have shown that land use determines whether residents have access to opportunities to engage in recreational-type physical activities in the neighborhood environment, which in turn promotes healthy behaviors. High-density agglomeration with a diverse mix of land development patterns is conducive to promoting residents' active lifestyles. Denser land use makes public goods and services easily accessible to every citizen. Residents' recreational needs are met in their

neighborhoods regardless of the mode of transportation. Land uses that are connected to residences within a relatively small location may provide competitively high and desirable densities for mixed-use applications. Promoting the integration of other components of a healthy city, such as sidewalks, diverse land uses, street connections, etc., leads to higher levels of physical activity. Refer Table 1.1 for the summary discussion of the land use aspect.

Urban form and design

Table 1.2 The impact of Urban form and design on healthy neighborhood

Planning factors		**keywords**	**Literature**
Urban form and design	Morphology and texture	Housing type Block pattern Built-up density Green ratio Size of neighborhood Block size Ratio between height and width Lighting Landscape elements Access to public space Attractiveness Car-parking design	Ferwati et al, 2019; Subramanian et al, 2021; Larimian et al, 2020; Khatibi et al, 2022; Juaidi et al, 2019; Yoo et al, 2016.

Summarizing the existing research, it is not difficult to find out that the mechanism of the design of urban space on the health of residents can be summarized into three main directions: "changing daily habits", "influencing the mode of travel and transportation" and "shaping the psychological perception experience". First of all, the scale, size, and density of the community will affect the behavior and psychology of the residents. Good architectural design and public space design in a community not only provide good ventilation and sufficient light, but also jointly convey the perception and feeling of beauty. At the same time, quiet and friendly community environment is inseparable from the creation of green natural environment, reasonable green vegetation not only in the landscape can improve people's visual environment, but also can play a role in reducing air pollution, noises and urban heat.

In addition, a proper height to width ratio, strong continuity, rich facade, the introduction of interactive furniture, well-equipped ground floor activities and service facilities are all elements that may attract people to stop or slow down, bring people rich living experience, promote physical activity and healthy interaction between residents, and enhance the sense of belonging to and satisfaction with the community.

Transport and movement networks

Table 1.3 The impact of Transport and movement networks on healthy neighborhood

Planning factors		**keywords**	**Literature**
Transport and movement networks	Motorized transport	Road density Automobile flow volume Connectivity Street hierarchy (types of roads/streets/paths in site) Parking lot	Wineman et al, 2014; Institute of Local Government, 2015; Ferwati et al, 2019; Hilley et al, 2020; Moroke et al, 2020; Zumelzu et al, 2019; Hachem-Vermette et al, 2019.
	Slow transport	Pedestrian Cycling paths Design details of slow transport system Green space incorporate with slow transport	Gulati, 2019; Gehrels et al, 2016; Wineman et al, 2014; Zumelzu et al, 2019; Stanislav et al, 2019; Zhang et al, 2020.
	Public transport	Number of metro stations Number of bus stops Accessibility to public transport	Wineman et al, 2014; Zumelzu et al, 2019; Liu et al, 2021; Stanislav et al, 2019.

Current studies suggests that transportation organization has a significant impact on the health of the population, which is divided into three main areas: motorized transportation, slow-moving transportation and public transportation. Among them, high density of road network and high connectivity of streets promote residents' positive lifestyles. As for slow-moving transportation, pedestrian width, length of sidewalk paths, length of cycling paths, dimensions of street blocks frontages, buildings' spatial relationships (back-to-back/side-to-side), block/plot's connection to its immediate surrounding context by public roads, semi-public roads, and alleyways all have influences on residents' well-beings.

With respect to public transportation, the greater the accessibility of public transportation stops, the more residents tend to walk or take transit, which promotes transit-based physical activity.

Green , blue and public open space

Table 1.4 The impact of Green , blue and public open space on healthy neighborhood

Planning factors		**keywords**	**Literature**
Green, blue and public open space	Scale	Amount of blue and green space Amount of public open space	Danladi et al, 2019; Plane & Klodawsky, 2013; Mouratidis, 2020; Gehrels et al, 2016; Li et al, 2017.
	Layout	Access to blue and green space Access to public open space Distance to blue and green space Distance to public open space Public open space design	Plane & Klodawsky, 2013; Mouratidis, 2020; Gehrels et al, 2016; Floyd et al, 2008.

In the study of blue-green and public open space and residents' health, it has been proved that it has a positive impact on residents' physiological and psychological health, which is mainly manifested in the ways of promoting physical activity and relieving psychological pressure. Influencing factors are mainly categorized into scale and layout. In terms of research objects, some studies focus on the accessibility, form and coverage of green space, while others focus on residents' satisfaction with the green landscape, perceived green quantity and perceived quality.

Evaluation systems for healthy communities

The concept of "automobile first" under modernization has led to much criticism of community environments, and "green" and "healthy" have become priority issues in community construction. Along with the advancement of the global healthy city movement and the deepening of theoretical research, the planning and construction of healthy neighborhoods have been gradually carried out in various countries around the world, and various construction indicators and assessment systems have enriched the practical connotation of healthy communities, which is of great significance in improving the living environment of the community and promoting the physical and mental health of the residents.

The BREEAM-Communities system, developed by the BRE in 1990, is the world's first methodology and evaluation system for assessing and measuring the sustainability of the built environment, and in 2009 BREEAM-Communities, a third-party, independent assessment standard based on the existing BREEAM methodology, was released for use in the evaluation of green communities (BRENNAN, 2008). Assessed as "a single block of multiple buildings, including public spaces adjacent to the block" or "multiple blocks integrated with public spaces". The LEED rating system developed by the U.S. in 1995 is a more commercially successful rating system for evaluating the comprehensive environmental performance of buildings, and gradually developed into a comprehensive evaluation system that includes multiple subsystems, and released LEED-ND (LEED for Neighborhood Development) in 2009(AJAY, 2009), which is divided into five dimensions and 56 sub-categories of indicators, aiming to comprehensively promote the ecological and sustainable development of communities. It has gained world-wide reputation by conducting certification activities in 114 countries. In addition, the Healthy Communities Program initiated by the Centers for Disease Control and Prevention (CDC) of the United States of America has formulated guidelines for healthy community action and experience in building healthy communities for different groups, such as children, adolescents, adults, smokers, and so on (CDC, 2010). The DGNB-NSQ system, jointly developed by the German Sustainable Building Council and the German government, is a national standard covering the entire industrial chain of the construction industry (DGNB, 2020). The entire system is supported by a rigorous and

comprehensive evaluation methodology and a large database of computer software. The DGNB-NSQ is assessed on at least two buildings and their common areas as a minimum unit, with a minimum size of 2 hectares. The GREEN STAR-Communities system was initiated by the Green Building Council of Australia (GBCA) in 2003 (Green Star, 2023). In 2012, the GREEN STAR-Communities system was developed in consultation with industry stakeholders, expanding the scope of the assessment from buildings to areas, including localities, neighborhoods, or other geographic areas that are relevant to the stakeholders. Most recently, the International WELL Building Institute (IWBI), with the goal of creating healthy, inclusive, equitable, integrated, and vibrant communities, published the Fitwel Certification System in 2019, a standard that covers 12 sectors to ensure healthy living for residents (Fitwel, 2019).

In this study, relatively mature standards and well-accepted evaluation systems are selected and their assessing dimensions are analyzed as follows (Table 1.5).

Table 1.5 The major evaluation standards of healthy communities

Evaluation Program	Evaluation dimension		Main Characteristics
LEED-ND	Smart location and linkage Neighborhood pattern and design Green infrastructure and buildings Innovations Regional priority		Provide standards for community construction at the level of green environmental protection and ecology
Fitwel Community Standard	Location Outdoor Spaces Stairs Dwellings Water Supply Vending Machines, Micro Markets, and Corner Stores	Access Entrances and Ground Floor Indoor Environments Shared Spaces Grocery Stores and Prepared Food Retail Emergency Procedures	Mainly through physical environment design and adequate community resources to promote the healthy development of community

Healthy Communities Program	Population Nutrition Tobacco Chronic disease management Leadership		Taking into account the wide range of actors, including residents, community institutions, health care units, schools, joint action is encouraged
DGNB-NSQ	Environmental quality Economic quality Sociocultural and functional quality Technical quality Process quality		The core issues addressed by the new version include climate action, climate adaptation and resilience
GREEN STAR-Communities	Governance Livability Economic prosperity Environment Innovation		The range of communities that can be used is very flexible, from small-scale to large-scale
BREEAM-Communities	Governance Resources and energy Transport and movement Innovation	Social and economic wellbeing Land use and ecology Community ownership	Alignment with the master planning process including a three-step process (establishing the principles, determining the layout and designing the details

It can be seen that the evaluation dimensions included in these criteria are related to ecological environment, physical environment, transportation system, public service and infrastructures, socioeconomic activities and community organization and management. Further analysis of the specific indicators under these evaluation dimensions (see Table 1.6) reveals that the emphasis of each standard is different. For example, as the focus of Healthy Communities Program mainly on the prevention of chronic diseases, more efforts has been made to encourage healthy behaviors rather than shaping a healthy built environment.

Table 1.6 Standardized indicators of major healthy communities

Dimensions	LEED-ND	Fitwel Community Standard	Healthy Communities Program	DGNB-NSQ	Green Star-Communities	BREEAM-Communities
Environment	Imperiled species and ecological communities conservation/ Wetland and water body conservation/ Mixed-use/ Compact development/ Reduced parking footprint/ Green building/ Rainwater management/ Heat island reduction/ Solar orientation/ Renewable energy production/ Wastewater management/ Solid waste management/ Light pollution management/ Brownfield Remediation	Diversity of land Use/Air Quality/ Water Quality/ Water Management Plan/ Heat Island Mitigation/ Building Certification/ Mixed-Income Housing/ Noise Mitigation/ Brownfield Remediation	--	Life-cycle assessment Pollutants and hazardous substances/ Urban climate/ Water cycle systems/ Land use/ Biodiversity/ Thermal comfort in open space/ Noise, exhaust and light emission/ Barrier-free design	Sustainable Buildings/ Integrated Water Cycle/ Greenhouse Gas Strategy/ Materials/ Sustainable Sites/ Ecological Value/ Waste Management/ Heat Island Effect/ Light Pollution	Land use/Landscape/ Ecology strategy/Rainwater harvesting/Low impact materials/ Sustainable buildings/ Noise pollution/ Water strategy/ Existing buildings and infrastructure/ Inclusive design/Adapting to climate change Flood risk management Light pollution Flood Risk Assessment

Dimensions	LEED-ND	Fitwel Community Standard	Healthy Communities Program	DGNB-NSQ	Green Star-Communities	BREEAM-Communities
Mobility	Smart location/ Access to quality transit/ Bicycle facilities/ Housing and job proximity/ Walkable street/ Access to civic and public space/ Access to recreation space	Pedestrian Network/ Open Space Access/ Transit Access/ Efficient Parking	Pedestrian/ Cycling facilities/ Disabled friendly walkways/ Green ways/ Access to green space	Mobility infrastructure -Motorized transport/ Mobility infrastructure -Pedestrians and cyclists	Access to Fresh Food/ Walkable Access to Amenities/ Sustainable Transport and Movement	Local vernacular/ Local parking/ Transport carbon emissions/ Transport assessment/ Safe and appealing streets/ Cycling network and facilities/ Access to public transport/ Public transport facilities
Resources and infrastructure	Local food for production/ Neighborhood schools/ Building and infrastructure reuse	Inclusive open Space/ Safe Street Infrastructure/ Bike Lanes and parking/ Trails and Green ways/ Playgrounds	Green space/ Stores with fresh food/ Schools/ Child health centre/ Mother-child friendly facilities	Open space Social and commercial infrastructure Energy infrastructure Smart infrastructure	Culture, Heritage and Identity Safe Places Digital Infrastructure	Delivery of services, facilities and amenities/ Public realm/ Green infrastructure/ Energy strategy

Dimensions	LEED-ND	Fitwel Community Standard	Healthy Communities Program	DGNB-NSQ	Green Star-Communities	BREEAM-Communities
Resources and infrastructure		Outdoor Fitness Area/ Community Gardens/ Restorative Garden/ Flexible Seating/ Arts and Culture Venue/Healthcare Facility/Childcare Facility/Civic Resource/Community Information/ Streetscape Events/Temporary Place making Plan/ Grocery and Food Markets/ Healthy Food Retail/ Local Produce/ Food Equity/ Safe Shelter	Space for sports activity/ Space for community activity			

Dimensions	LEED-ND	Fitwel Community Standard	Healthy Communities Program	DGNB-NSQ	Green Star-Communities	BREEAM-Communities
Socioeconomic well-being	Affordable housing		Employment opportunities by race/ Education and Skills	Life-cycle costs/ Resilience and adaptability/ Land use efficiency/ Value stability/ Environmental risks/ Social and functional mix	Community Investment/ Affordability/ Employment and Economic Resilience/ Education and Skills/ Development Return on Investment/ Incentive Programs/ Peak Electricity Demand Reduction	Economic impact/ Demographic needs and priorities/ Housing provision/ Training and skills
Management	Community outreach and involvement	Community Engagement/ Occupant Satisfaction Survey/ Survey Results/ Implementation/ Emergency Preparedness Plan/ Emergency Volunteers	Public participation	Resource management/ Participation/ Integrated planning	Environmental Management/ Adaptation and Resilience/ Corporate Responsibility/ Sustainability Awareness/ Community Participation and Governance	Consultation and engagement/ Community management of facilities

On the environmental side, most of the standards emphasize favourable ecosystems such as biodiversity, wetland protection, clean air and water, but also include adaptation strategies to negative environmental impacts (e.g., flooding, urban heat islands, brownfield, noise, waste, light pollution, etc.). In terms of the built environment, green buildings, energy efficient buildings, compact layouts and diverse land use patterns are promoted. In terms of transportation, it emphasizes the accessibility of settlements to surrounding public facilities (including open space, blue-green space, recreational and cultural space, etc.), and encourages public transportation to connect with the settlements and the construction of pedestrian/bicycle-friendly road networks in terms of transportation modes. It can be seen that all the standards pay particular attention to leading an active lifestyle for residents, recognizing that physical and leisure activities can remove negative emotions and improve resistance to chronic diseases. This trend can also be seen in the resources available for public resources and infrastructures, in terms of land for education, commerce, recreation, and sports. At the socioeconomic level, indicators are more scarce, with a focus on affordable housing and education and technical training for residents. Finally, at the community management level, the contribution is dominated by public participation, with only Fitwel and Green Star-Communities talking about crisis response and management.

1.4.3 Post-pandemic

Given current and future global challenges confronting urban populations, planning cities to mitigate and adapt to future pandemics, climate change, and disasters must be a priority. The impact of pandemics highlights the need for cities to be resilient and designed to support the health of urban residents in coping with future health shocks.

Post-pandemic and urban normalization of prevention and control

The post-pandemic era is an era of gradual passing of corona-viruses, but not a complete disappearance, accompanied by small ups and downs and small outbreaks. Therefore, the prevention and control policy of cities has changed from "total blockade" to "normalized prevention and control". Normalized prevention and control of infectious diseases is an effective way to face urban construction in the post-pandemic era, and is an important

measure to restore the social economy and ensure the safety of residents in the post-pandemic era. Normalization mostly refers to the tendency to the normal state, and the normalization of infectious disease prevention and control is a kind of preventive consciousness towards the danger, which can enhance the sustainable development of the city (Hesse & Rafferty, 2020). Normalized prevention and control of infectious diseases means that the prevention and control of pandemics are carried out together with the resumption of social and economic activities, which means that the economic and social development of the city is carried out at the same time with the risk assessment, prevention and control of infectious diseases.

In view of the characteristics of infectious diseases, there are three major principles for the prevention and control of infectious diseases, firstly, cities need to improve their abilities to resist infectious diseases, and the urban planning perspective can enhance residents' immunity by increasing green space and activity space. Secondly, cities can improve the conditions of environmental health, deal with the community ecological environment and the ventilation and sewage design inside the building. Finally, the public health prevention and control management system can be strengthened, and medical service facilities can be reasonably and comprehensively allocated to reduce the distance between residents and public service facilities. The links in the prevention and control of infectious disease transmission include pathogen-host-transmission pathway-susceptible host-pathogen elimination. Interference with any of these links from a planning perspective will inhibit the spread of infectious diseases and can control the dissemination in a short period of time.

Cities and settlements in the post-pandemic era

Although the impact of COVID-19 has gradually diminished, it has had a profound effect on cities and settlements in recent years. A number of studies describe the main impacts of the COVID-19 pandemic and predict possible future trends. So far, taking the Web of Science (WoS) database as an example, the term "cities" had 649412 articles published and 135 are identified that presents the combination of the term "post-pandemic". Among them, 36 are about Urban studies, 30 are about Public environmental occupational health, 27 are about Environmental sciences, 23 are about Green sustainable science technology, 16 are about

Constructing Building technology, and 7 about Geography and so on. Detailed information can be found in Figure 1.5.

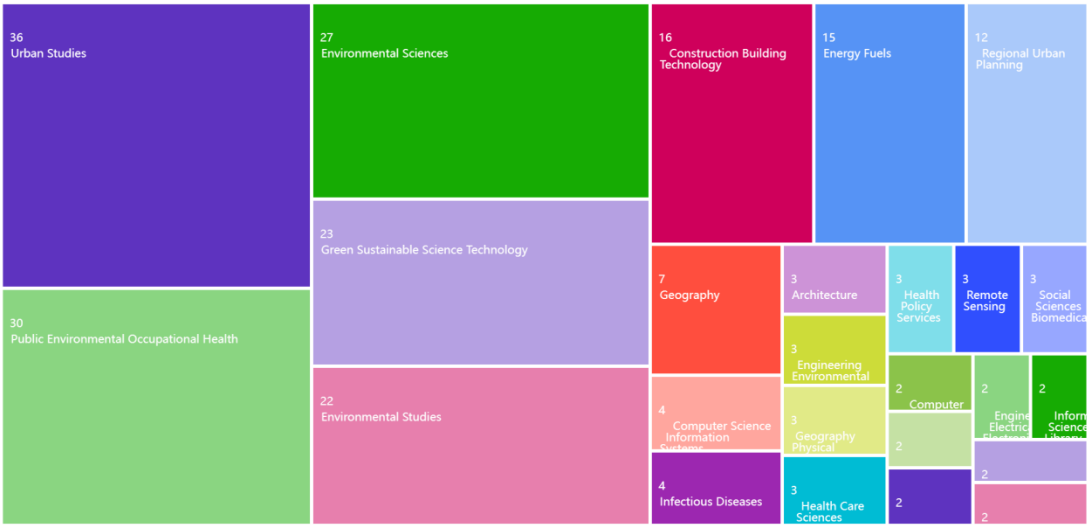

Figure 1.5 Distribution of Post-pandemic Research in different disciplines

Synthesizing these findings, in terms of research hotspots, research on post-COVID-19 cities and settlements is mainly concerned with environmental quality, socio-economic impacts, management and governance, and urban design. While this demonstrates the diversity of research agendas, environmental quality, which covers issues related to air quality, meteorological parameters, and water quality dominates. Improvements in urban air and water quality during the lockdown highlighted the significant environmental impacts of human activities and served as a wake-up call for urban development (Şahin M, 2020) and a reminder of the need for cities in the post-pandemic era to follow sustainable development patterns (see in Figure 1.6). In addition, the pandemic exposed old socio-economic inequalities that existed in the city, manifested in the extreme lack and unbalanced distribution of public resources in the city (Shirazi et al., 2020). In particular, the government's poor crisis management and the need for rethinking transportation and settlement design patterns are in the spotlight. Building sustainable, equitable, inclusive and healthy urban and community environments in the post-pandemic period has been prioritized.

On the other hand, the COVID-19 pandemic has also affected the lives of most of the citizens

across the globe. As a result of the pandemic in some parts of the world, quality of life areas and health and well-being outcomes deteriorated (Brooks et al., 2020). The quality of life in cities was challenged and changed during the pandemic. Patterns of activities such as living, working, seeking medical care, shopping, physical activity, recreation, and socializing were dramatically rewritten (Mouratidis & Papagiannakis, 2021). The role of housing, local communities, different modes of transportation, and information and communication technologies (ICT) in quality of life also changed radically.

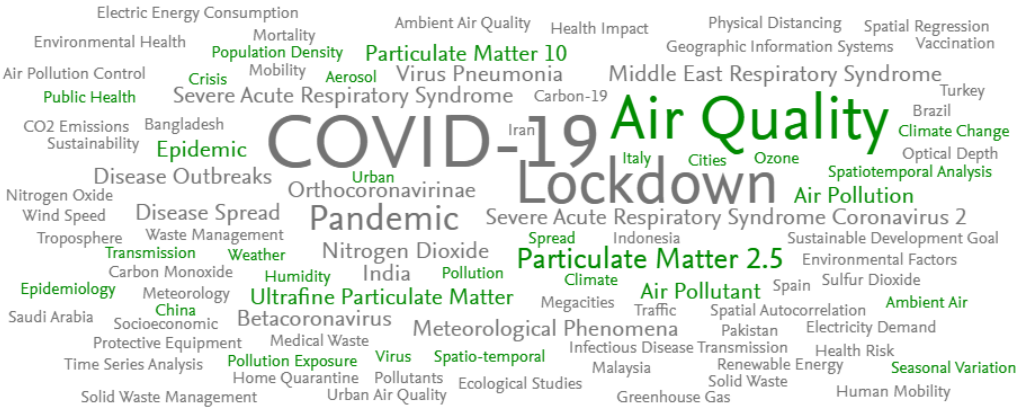

Figure 1.6 Distribution of Hot spots of Post-pandemic Research

Hence, in light of the aforementioned transformations, urban planning and design must adapt. This signifies that the pandemic is either in the process of or has already fundamentally altered the urban landscape (Figure 1.7). Confronted with numerous challenges, cities are now navigating the "post-pandemic" era.

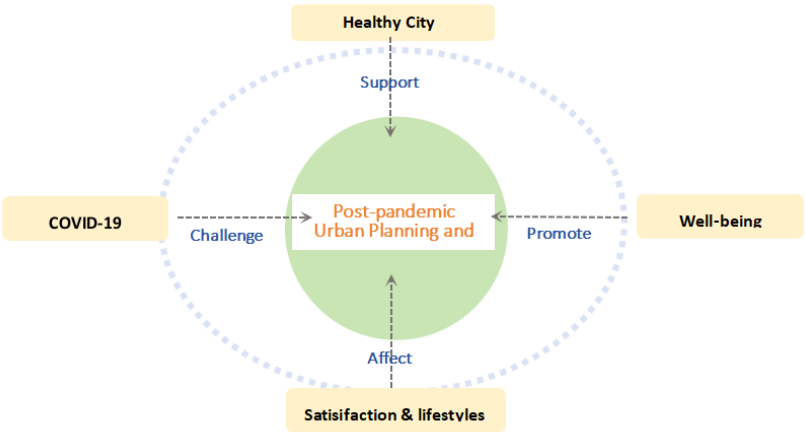

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Figure 1.7 Post-pandemic Urban Planning and Design Structures

1.5 Conclusion

Urban planning, as a discipline closely related to public health, has always been dedicated to the promotion of public health. With modernization, the city has built up a scientific system of housing, transportation, greenery, public space, health care, and municipal facilities as it continues to fight epidemics. The practice of promoting healthier cities and settlements has deepened around the world, especially with the evolution and development of the healthy city theory, which began at the end of the last century.

The COVID-19 pandemic that swept the world in the spring of 2020 has refocused the academia's attention on pandemics that were previously thought not to pose a significant threat, and at the same time exposed the lack of preparedness of urban planning to withstand sudden public health crises. In particular, the theory of healthy cities has long been concerned with the prevention and treatment of chronic diseases, and its main tool is to promote active lifestyles (e.g., walking and cycling networks, ecologically friendly natural environments, and the distribution of abundant public facilities and resources within close proximity) to enhance the immunity of the residents and promote their health. However, there is still a gap in the programs and strategies on how to deal with the infectious diseases. The lack of attention to the socioeconomic and community management dimensions of pandemics has also increased inequalities worldwide. The large number of quarantine policies in place has left grass-roots organizations without the necessary resources to face the crisis, thus slowing down the rate at which the pandemic is being contained.

Simultaneously, the pandemic has quietly reshaped population lifestyles, rewriting patterns of living, working, transportation, shopping, education, entertainment, physical activity, and socializing. The increased reliance on information and communication technologies (ICT) within cities underscores a growing trend toward localization, challenging established urban layouts and patterns. The current era, often referred to as the "post-pandemic" period, has become a pivotal focus for research on cities and settlements. Urban planning now grapples with critical questions: What kind of trends will be brought to urban planning? Are these changes temporary or enduring, and what are the long-term implications? How can the

lessons learned from the Coronavirus be utilized to create healthier, resilient, inclusive and sustainable urban settlements?

Chapter 2: Systematic review of urban planning's response to pandemics

2.1 Introduction

Urbanization and industrialization have ushered in public health challenges (Susser, 1996), with new infectious diseases emerging annually, posing a significant and ongoing test with profound implications for the future of humanity (WHO, 2007). In early 2020, the coronavirus became a recurring trial for major cities worldwide. Confronted by the pandemic, cities laid bare numerous governance, spatial structure, and public service provision issues, exposing potential discrepancies in responses from one city to another (Anttiroiko, 2021). Positioned at the heart of the crisis storm (Parysek & Mierzejewska, 2022), cities have once again evolved into tightly interconnected communities of shared human destiny. Reflecting on the lessons and deficiencies revealed in cities' responses to the pandemic and delving into strategies for future urban development stand as paramount concerns demanding profound contemplation from every urban planner and policy implementer (Mouratidis & Yiannakou, 2022).

The historical connection between urban planning and public health dates back significantly. Past severe public health crises not only led to the inception of the public health discipline but also indirectly contributed to the emergence of modern urban planning (Wang, 2021). The 19th-century challenges posed by typhoid and cholera prompted the development of sewage and water systems to combat pathogens, culminating in sanitary advancements. In the 20th century, responses to the Spanish flu included the construction of numerous parks, promenades, and squares in Europe as early attempts to provide safer urban spaces. Movements such as the garden city, city beautiful, and environmental movements played essential roles in shaping modern urbanization (Hall, 2002), laying the theoretical groundwork for the discipline of urban planning.

However, the advent of the "germ theory" in the medical field shifted the focus of public

health research from spatial environment construction to bacteriological study (Jason, 2009). It wasn't until 1986, with the launch of health promotion by the World Health Organization (WHO), that the urban environment regained prominence as a crucial element in health support. This led to extensive research on healthy urban planning, primarily centered on preventing and controlling chronic diseases and promoting physical activity, with limited attention to infectious diseases. The landscape changed in 2020 when pandemics, once again, became the focal point of urban planning. Addressing the urgent need to prevent and mitigate the spread of infectious diseases became a critical gap in the discipline (Allam & Jones, 2020). At the onset of the pandemic, numerous studies highlighting lessons from inadequate responses underscored that our cities lacked a systematic theory and framework for effective pandemic response (Syal, 2021). Specifically, in urban planning, challenges such as excessive construction density, disruptions in transportation and logistics, poor information communication, a shortage of medical and public services, and an uneven spatial distribution of green spaces emerged as significant obstacles to controlling the pandemic.

COVID-19 has significantly impacted cities, with many of its challenges rooted in urban patterns, environmental quality, and the socioeconomic and health status of populations. Consequently, cities must adapt their urban planning models and principles to effectively address the pandemic (Batty, 2020). With the World Health Organization (WHO) declaring on May 5, 2023, that COVID-19 no longer constitutes a "public health emergency of international concern," a comprehensive review of urban planning responses becomes imperative. Examining urban planning research on the COVID-19 pandemic over the past three years in comparison to previous experiences can provide insights into the theoretical and methodological changes brought about by COVID-19. However, such comparative studies are currently scarce. The limited comparisons available often focus on the period between COVID-19 and the 1918 flu, overlooking the significant changes in human society's production and lifestyle over the past century (Nichols et al., 2020). Considering the processes of globalization, advancements in medicine, epidemiology, and information technology have transformed the experience, understanding, and control of pandemics. In contrast, H1N1, which circulated from early 2009 to late 2010 and caused at least 575,000

deaths worldwide, offers a more relevant comparison to COVID-19. Leveraging surveillance systems and computational power not available to its predecessors, various models were developed to assess the pandemic's impact and the effectiveness of potential control measures during H1N1 (Yang et al., 2009). Therefore, H1N1 and COVID-19 provide an opportunity for comparison given their similar historical and technical backgrounds.

Against this backdrop, the scope of this study narrows down to COVID-19(2019) and H1N1(2009). From observing the specific performance of urban planning response to these two pandemics in literature, research questions mainly concerned: (1) What urban planning theories and models have been used for the two pandemics? Are there any new ones emerging? (2) Over the past decade, from H1N1 to COVID-19, what changes have taken place in urban planning to cope with pandemics, identifying whether COVID-19 has upgraded capacities/theories/techniques, in which presents the future trends?

2.2 The methodology of systematic review

The research developed a systemic literature review protocol supported by Petersen et al., (2015) (Petersen et al., 2015). This part illustrates the methodology in following three steps, which are (1) Paper searching, screening and selection; (2) Bibliometric analysis which include general statistics analysis and network analysis; (3) Detailed analysis.

The following diagram (see in Figure 2.1) further illustrates the connections between above methods and research objectives.

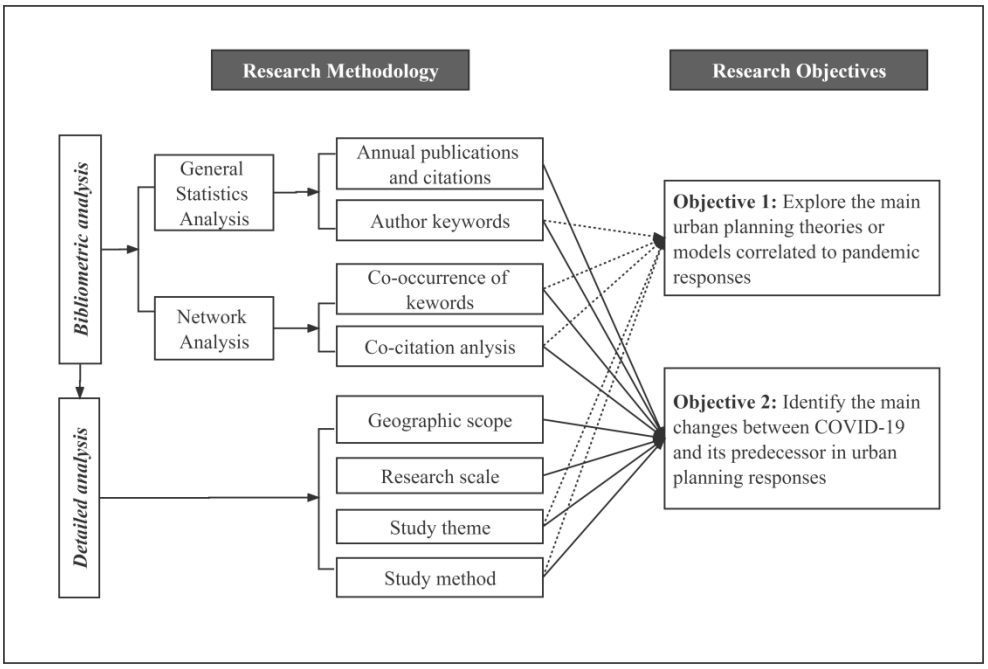


Figure 2.1 Schematic diagram of this comparative review.

2.2.1 Search strategy and Selection criteria

Data collection and identification

The study focuses on relevant papers indexed in the Web of Science (WOS), a widely used database for scientific articles. The search was restricted to peer-reviewed articles published by reputable academic publishers.

Corresponding to the second research question which sought to determine if there were any changes in the theoretical application and practical tools of the COVID-19 response from the previous one, the search was carried out in two individual lines. To better compare the COVID-19 and H1N1 response, the search formula was exactly the same as keywords comprised one term from “pandemic” or specific virus name like “h1n1”, “swine flu”, “covid”, “coronavirus” and one term from “city” feature words like “cities” or “urban”, and one term form “planning” or “design”. According to the time periods of the two pandemic outbreaks, they were searched respectively.

For h1n1: TITLE-ABS-KEY (“pandemic” OR “h1n1” OR “swine flu”) AND (“urban”

OR “city” OR “cities”) AND (“planning” OR “design”) between the publication year of 2009 to 2019;
For covid: TITLE-ABS-KEY (“pandemic” OR “covid” OR “coronavirus”) AND (“urban” OR “city” OR “cities”) AND (“planning” OR “design”) between the publication year of 2020 to 2022;

Furthermore, urban theories keywords were not directly included in the entire search process, deviating from the approach of a previous study (Machado & Ribeiro, 2021). This departure was intentional to avoid predetermined biases regarding which theories might be pertinent to pandemic response, aiming for an unbiased deduction of the correlation of urban theories from the obtained results.

Screening and Eligibility

Through an iterative searching cycle spanning from September 2021 to May 2023, a total of 3,123 articles related to both COVID-19 and H1N1 were identified. Initial screening revealed that many articles, despite including the specified keywords in the title or abstract, were primarily related to other disciplines such as medicine, pharmacy, or nursing. To refine the focus, the filtering function of Web of Science was employed, resulting in 496 articles remaining after selecting only the category of "urban studies." Additionally, materials identified as book chapters, book reviews, letters, editorials, and notes were excluded due to a lack of keywords suitable for network analysis.

Upon reviewing the abstracts of the remaining articles, those that only mentioned the terms "covid" or "h1n1" in passing rather than as a central focus were excluded. After this stage, 334 articles remained in the database. A further review of the full-text of these articles, applying six inclusion criteria, led to the removal of 228 articles that did not meet all the criteria. The inclusion criteria specified that articles must (1) propose a response or solution to the pandemic from a theoretical perspective, not just an operational one; (2) be urban planning-related rather than discussing certain aspects alone, such as water, food, finance, etc.; (3) study the city or larger geographic areas rather than focusing solely on public space or

architecture; (4) focus on H1N1 or COVID-19 only; (5) concentrate on urban areas, not rural areas; and (6) be written in English.

Additionally, 15 papers were added to the database through scrutiny of reference lists. In the end, 129 studies were included, with 30 from H1N1 and 99 from COVID-19 (Figure 2.2).

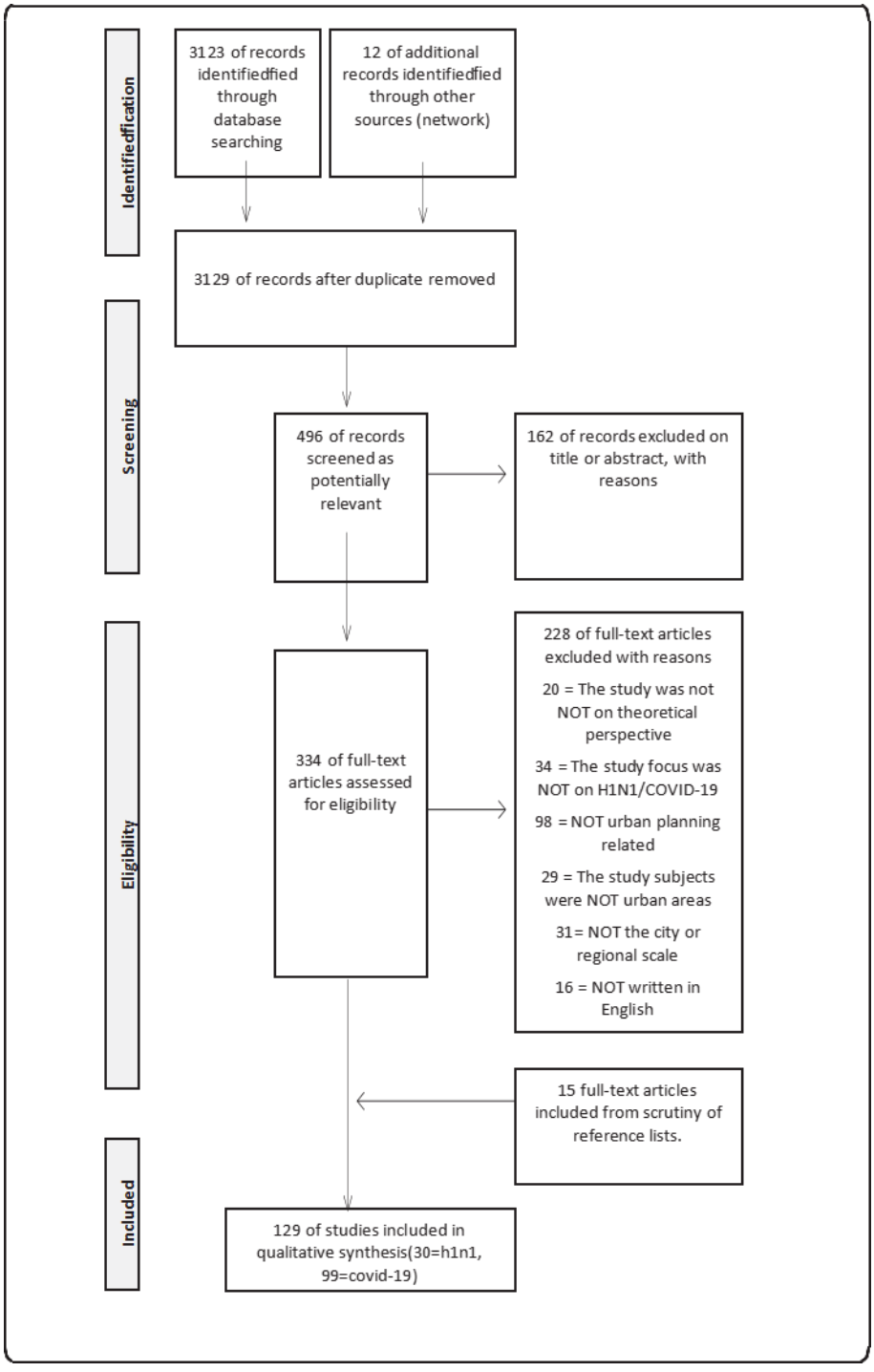


Figure 2.2 Flow diagram summarizing the literature search process.

2.2.2. Bibliometric Analysis

Two data extraction sheets were meticulously crafted in Microsoft Excel, each dedicated to collecting information from papers pertaining to H1N1 and COVID-19 topics, respectively. Initially, crucial data such as titles, authors, publication years, author keywords, and total as well as per-year citations were meticulously sourced from Web of Science. The author keywords served as valuable indicators of applications related to specific urban concepts or theories, warranting specific attention.

The network analysis encompassed co-occurrence keyword analysis and co-citation analysis. Given that keywords encapsulate the essence of research concepts, methodologies, and themes, employing co-occurrence keyword analysis was instrumental in unveiling patterns and trends across various domains associated with pandemic responses (Dotsika & Watkins, 2017). Simultaneously, co-citation analysis facilitated the identification of the most widely referenced publications, especially to ascertain if there was co-reference to the same urban theories or concepts in the responses to both H1N1 and COVID-19. Both analyses, grounded in network theories, have been empirically validated as highly effective in discerning concepts with integrative characteristics. Consequently, these methods were applied in this study to expeditiously unveil the potential theoretical framework in urban planning responses to the two pandemics.

Leveraging the VOSviewer software (Van & Waltman, 2016), the outcomes of the network analysis were adeptly presented. A minimum of two variables, be it co-occurrence or co-citation, could be set as a threshold for interactions. The total strength of bibliographic coupling linkages with other items was meticulously calculated. Node size conveyed the frequency of keyword occurrence or citation, while the distance between nodes signified their relative co-occurrence or co-citation. The analytical approach, involving the "LinLog method and modularity clustering technique," was employed to illustrate the network map, wherein same-colored keywords were clustered together. This method facilitated the identification of rapidly expanding subjects and collaborative regions in the realm of urban planning responses to pandemics. Additionally, particular emphasis was placed on scrutinizing the growth of

scientific concepts and propositions through their evolutionary processes. The "Overlay visualization technique" was chosen to delineate the shift in focus from H1N1 to COVID-19 over time, aligning with the average year of keywords in the co-occurrence network.

2.2.3. Detailed Analysis

The in-depth analysis aimed to delve into the novel research areas, principles, methods, and tools that surfaced in urban planning during the COVID-19 era. While the preceding bibliometric analysis provided a broad differentiation between the two periods in terms of the number of studies and research hotspots, it fell short of delving deeper into the evolutionary changes within urban planning in response to pandemics. Consequently, a meticulous review was imperative. Employing an inductive content-analysis method (Noack, 2007), which extrapolated comprehensive insights from fragmented information, all included papers underwent categorization based on geographic scope, research scale, study method, and specific theme. These categorizations were systematically filled into the table mentioned in section 2.2. To ensure a controlled and consistent data analysis of the target literature, two authors conducted multiple meetings during the data collection phase and initially developed a standardized data extraction form using Excel. A preliminary review was then conducted, with two authors independently extracting information from the same set of publications within the target literature. The results demonstrated an agreement rate of over 90%. After reexamining the contents for reasonableness, partial adjustments were made to the data extraction sheet. Following this step, both authors meticulously reviewed all publications and completed the final information extraction. By scrutinizing the similarities and differences between H1N1 and COVID-19 studies from the sheet, a more nuanced understanding of the trends in the development of urban planning in response to pandemics was achieved.

2.3. The results of systematic review

Corresponding to the two main research methods, the results section first presents a statistical comparison of the two parts of the literature on the topic of H1N1 and COVID-19, followed by a detailed description of the results of thematic analysis for both.

2.3.1. General Statistics of Publications

Annual Publications and Citations

The discrepancy in the number of publications between the literature on H1N1 and COVID-19 was notably pronounced, as reflected in the results of the search process. Figure 2.3 provides a detailed breakdown of annual publications and citations, confirming this disparity. In the two years spanning the emergence of swine flu in early 2009 to the World Health Organization's declaration of its end in late 2010, only five articles were included as target literature. Up until the end of 2019, review articles related to H1N1 were updated at an exceedingly sluggish annual rate. Conversely, in 2020, urban studies swiftly responded to the global outbreak of the COVID-19 pandemic with 20 publications, escalating to 60 in 2021. A similar doubling increase rate was observed in citations, indicating a rapidly growing interest in this field. Although the number of studies started to decrease sharply in 2022, the volume of citations remained significant.

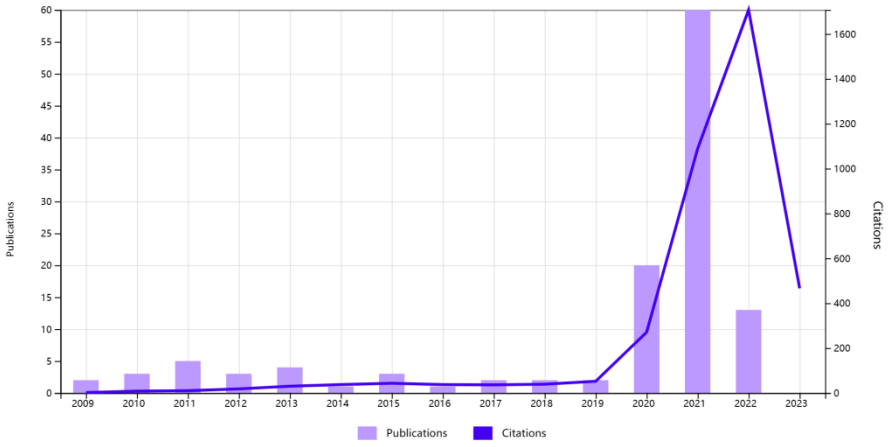


Figure 2.3 The number of included articles by year (2009–2022).

Author Keywords

By conducting a keyword count, a total of 12 urban theories were identified. The most extensively studied urban theory was 'resilience', followed by ‘smart cities’ and ‘sustainability’. The remaining urban theories included ‘vulnerability’, ‘healthy city’, ‘15-minute city’, ‘compact city’, ‘tactical urbanism’, ‘temporal urbanism’, ‘informal urbanism’, ‘livable city’, and ‘Weberian city’. Notably, there was limited association between H1N1-related research and urban theories, with the author keywords 'vulnerability'

and 'Weberian city' appearing only once each. In contrast, a diverse array of urban theories emerged from COVID-19-related urban planning studies. An additional point of interest lies in the interconnection between urban theories. Within the selected target articles, it was not uncommon for multiple urban theories to co-occur in authors' keywords. The combinations "resilience" and "smart cities" and "resilience" and "sustainability" appeared most frequently, along with other pairings such as "resilience" and "vulnerability", ‘smart cities’ and ‘tactical urbanism’, and ‘sustainability’ and ‘livable city’. These associations suggest that these theories often overlap, offering complementary perspectives on effective pandemic prevention and control strategies.

2.3.2. Network Analysis of Publications

Keywords Co-Occurrence Analysis

After combining keywords with synonyms and eliminating low-frequency words, a cluster of keywords and a co-occurrence network were generated. Out of the 647 keywords (including author keywords and keywords plus), 139 keywords met the threshold requirement of at least three occurrences.

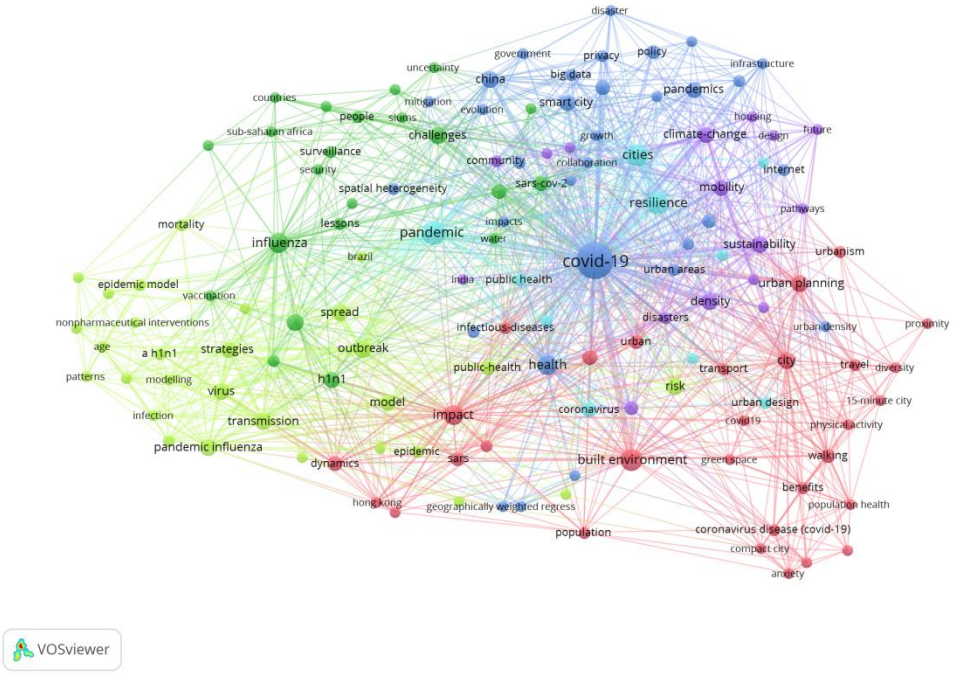


Figure 2.4 Keywords co-occurrence analysis of H1N1 and COVID-19 responses in urban planning.

As depicted in Figure 2.4, it is evident that COVID-19 played a significantly more prominent role in urban studies related to pandemic response compared to H1N1. The analysis revealed robust connections with the terms “resilience” (15 occurrences, 44 links, and 76 total link strength), “smart cities” (12 occurrences, 39 links, and 63 total link strength), and “sustainability” (9 occurrences, 34 links, and 47 total link strength). Following closely was “vulnerability” (5 occurrences, 21 links, and 29 total link strength), making up the primary four urban theories. Although 12 theoretically relevant keywords were collected in the author keywords above, the analysis now indicates that the other words did not occur with sufficient frequency to be included in the main theories responding to pandemics.

There were a total of six clusters, each accounting for approximately 21% (YELLOW-GREEN), 16% (GREEN), 7% (LIGHT BLUE), 23% (DARK BLUE), 11% (PURPLE), and 22% (RED) of all keywords, respectively. Keywords in the same color signify their close association and more established research ties. In this context, "vulnerability" demonstrated a strong connection to the "preparedness" phase, particularly concerning populations, slums, uncertainty, etc. The scope of "smart cities" was more concentrated on the "urban governance" dimension, closely aligning with big data, infrastructure, and urban policies. In contrast, keywords closely associated with "sustainability" and "resilience" did not focus on a specific area. For instance, within the "sustainability" group, there were both "climate-change" and "mobility," "density," "housing," while the "resilience" group included "urban form," “public health," and "pandemic planning."

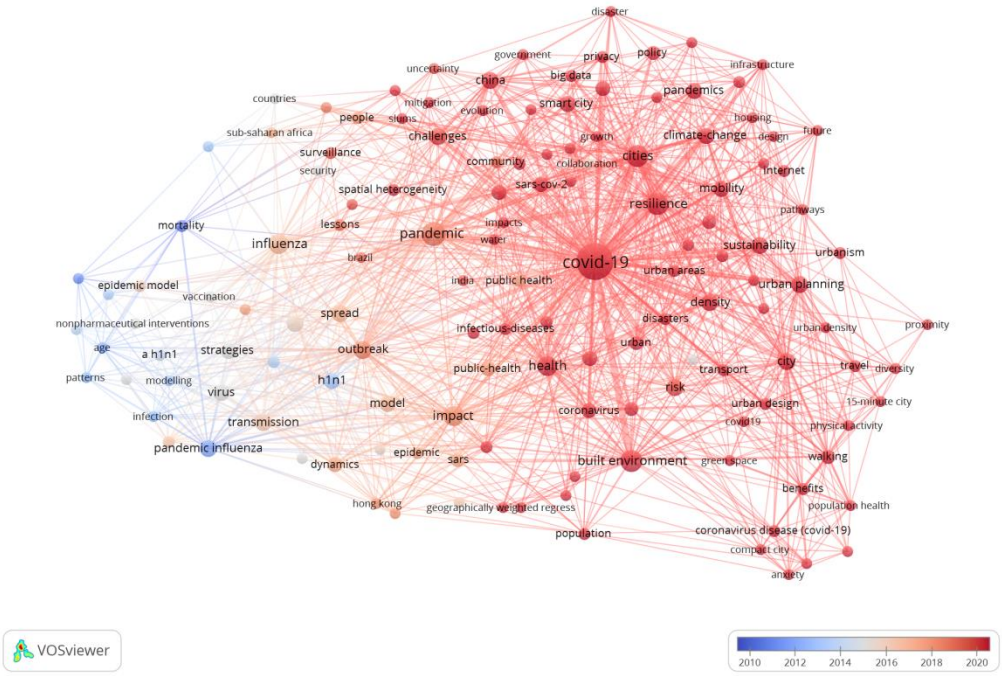


Figure 2.5 Keyword co-occurrence analysis of H1N1 and COVID-19 responses in urban planning overlaid with time (2009–2022).

The evolution of research domains from 2009 to the present is evident in the outcomes of keyword co-occurrence analysis, as illustrated in Fig. 2.5, utilizing the "Overlay Visualization." Among the 139 keywords, 45 were associated with H1N1, while the remaining 94 words were linked to COVID-19. The color transition, shifting from cold to warm tones (representing the time span from 2010 to 2020), reveals three main periods:

--- 2009-2015 (in blue to grey)

High-frequency keywords during this period included "virus," "pattern," "modeling," "transmission," "strategies," "school closure," "vaccination," and "NPIs" (Non-Pharmaceutical Interventions).

--- 2016-2019 (in flesh to salmon pink)

High-frequency keywords during this period included "impact," "preparedness," "public-health," "people," "slum," "lessons," and "pandemic planning."

--- 2020-2022 (in red)

High-frequency keywords during this period included "resilience," "sustainability," "smart cities," "vulnerability," "built environment," "density," and "mobility."

It is noteworthy that keywords related to H1N1 before 2020 largely overlapped with the YELLOW-GREEN and Green clusters from the network map. This suggests that studies related to H1N1 focused more on procedural phases, such as virus "transmission," "intervention" methods, and "preparedness" for pandemic planning. The application phase of H1N1 studies remained in the 'mid-pandemic' and 'pre-pandemic' contexts. In contrast, COVID-19 studies concentrated more on the 'post-pandemic' outcomes, exploring how to construct more desirable cities (especially in terms of management and environment). This trend is reflected in studies linking the pandemic to urban theories, aligning with the BLUE, LIGHT BLUE, PURPLE, and RED clusters.

Co-Citation Analysis

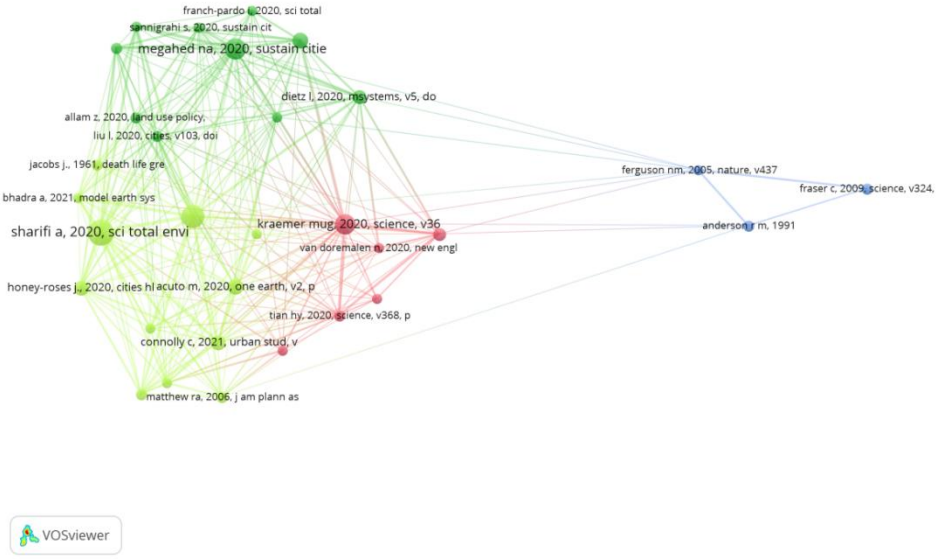


Figure 2.6 Co-citation analysis of H1N1 and COVID-19 responses in urban planning with 31 top-cited papers between 2009 and 2022.

There were 6,757 references across all included papers, with 31 papers meeting the threshold of a minimum of 6 citations for a cited reference (Figure 2.6). Notably, the highest co-cited references were concentrated after the year 2020, suggesting a lack of strong research continuity between COVID-19 and H1N1. This also implies the emergence of a new framework for responding to outbreaks during the COVID-19 period. Pre-2020 literature with the highest number of co-citations primarily clustered around three articles published from 1991 to 2009. These articles, represented by the same color, exhibited a high degree of association, focusing predominantly on strategies for mitigating pandemics. Table 2.1 provides a summary of the top four papers with the highest co-citation frequency (all published in 2020), including their titles, sources, and key ideas. These papers offer crucial insights into understanding the mechanisms of pandemic responses and the evolving domains of knowledge.

Table 2.1. Top four papers with the highest co-citation frequency.

Rank	Title	Co-citations	Ideas
1	The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management (Sharifi & Khavarian-Garmsir, 2020)	22	COVID-19 offers great opportunities for planners and policy makers to make transformative actions
2	Does Density Aggravate the COVID-19 Pandemic? Early Findings and Lessons for Planners (Hamidi et al., 2020)	20	Planners should continue to promote dense development
3	Antivirus-built environment: Lessons learned from Covid-19 pandemic (Megahed & Ghoneim, 2020)	17	An antivirus-built environment paradigm is needed
4	The effect of human mobility and control measures on the COVID-19 epidemic in China (Kraemer et al., 2020)	15	Shows how control measures implemented in China mitigated the spread of COVID-19

Upon examining the objectives and themes of the four highest co-cited papers, it becomes apparent that the topics have shifted in different directions compared to the pre-2020 period. The main shifts include a focus on (1) public emergency response, (2) a health geography basis for decision-making, and (3) rethinking urban structure and form. The post-2020 studies

on public emergency response build upon previous findings that national-level public intervention can slow the spread of the virus. However, the significance of travel restrictions (Tian et al., 2020) was more extensively discussed during the COVID-19 period than the previous emphasis on household-based prophylaxis coupled with reactive school closure (Qualls et al., 2017). Furthermore, a considerable number of studies utilized Geographic Information System (GIS) as a fundamental tool for spatiotemporal analysis and disease mapping, tapping into various urban socioeconomic variables (Li et al., 2021). This approach provided a robust foundation for the development of pandemic policies (Lak et al., 2021). Insights from geography increased attention and understanding of informal settlements and their inhabitants (Wilkinson, 2020), aiming to reduce the sacrifice or lack of protection of marginalized populations (Hassankhani et al., 2021). The last notable direction was the unprecedented opportunity for positive urban transformation (Sharifi & Khavarian-Garmsir, 2020), given that pandemics have dramatically changed the structure of cities and the lifestyles of their inhabitants (Acuto, 2020). Urban planning studies during the COVID-19 period, with a focus on these three main directions, present a more comprehensive and interdisciplinary perspective than those during the H1N1 period.

2.3.3. Detailed Analysis of Publications

Geographic Scope and Research Scale

The findings related to the geographical scope of the studies indicate that urban planning responses during the H1N1 period primarily concentrated on countries in the Americas, Oceania, Europe, and Asia, including the United States, Mexico, Chile, New Zealand, Australia, England, Italy, Hungary, China, and India. In contrast, studies during the COVID-19 period expanded to include Africa and the MECA (Middle East and Central Asia) countries. Furthermore, during the H1N1 period, the focus was predominantly regional or national, with less than one-third of the studies conducted at the urban scale. In contrast, the COVID-19 period witnessed a significant increase in city-based and local responses, constituting 79% of the total number of targeted articles. Numerous case studies focused on specific cities, such as New York, London, Chicago, Madrid, Bogota, Hong Kong, Wuhan, Tehran, among others.

Study Methods

The study methods employed in the included papers were categorized into four types: review, conceptual, empirical, and modeling (Hanson et al., 2020). Notably, the review method dominated in H1N1 studies, accounting for 63%, while its prevalence decreased to 26% in COVID-19 studies due to the emergence of conceptual approaches (14%) and the broader integration of empirical and modeling methods (27%). Additionally, a new category emerged after 2019, combining the review and conceptual approaches, constituting 10% of the study methods (refer to Fig 2.7). Conceptual and conceptual with review articles were particularly focused on exploring the impacts of pandemics on cities, identifying opportunities and challenges, and seeking effective strategies. This category accounted for 75% of the urban theory keywords identified. The combination of empirical and modeling approaches was popular in both H1N1 and COVID-19 literature, primarily relying on case studies that examined the relationship between urban factors and pandemic outcomes through methods such as surveys, questionnaires, interviews, and computer modeling. Among these approaches, modeling was the most frequently used, although its connection with urban theories was comparatively weaker.

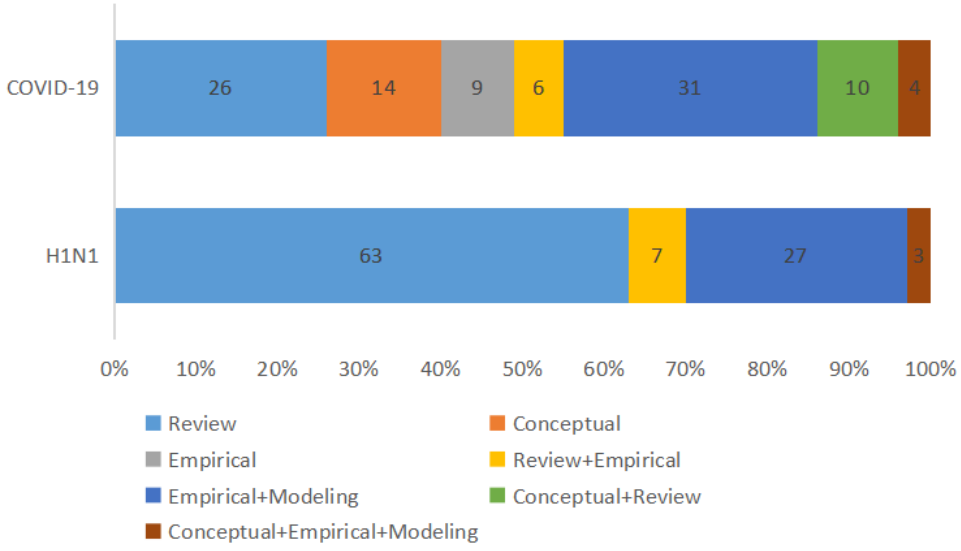


Figure 2.7 Comparison of study method with percentage.

Study Theme

The total of 129 articles synthesized in Section 2.2 were categorized into five specific themes: (1) Governance and Policy; (2) Built Environment; (3) Modeling; (4) Socioeconomic Factors; and (5) Post-COVID Planning. Table 2.2 presents the distribution of publications related to H1N1 and COVID-19 across these study themes. Urban theories, identified through author keywords and marked in the information extraction sheets, were associated with each theme, providing insights into the theoretical background of the studies.

For H1N1-related research, the majority (57%) was concentrated in 'Governance and Policy,' with 33% focusing on 'Modeling.' However, in COVID-19-related studies, these percentages sharply declined to 13% and 10%, respectively. Notably, the research landscape shifted towards future-oriented urban planning, constituting 35% of the overall articles, a theme not explored during the H1N1 era. Similar patterns were observed in the 'Built Environment' category, where the contribution rate surged to 10% during COVID-19 studies, a notable departure from the absence of such research during the H1N1 period. Research on 'Socioeconomic Factors,' present during the H1N1 period, saw a significant increase during the COVID-19 outbreak, rising from 10% to 32%. The association of H1N1-related research with urban theories was limited, with only 'vulnerability' and 'Weberian city' appearing once each in the 'Governance and Policy' theme. In contrast, COVID-19-related urban planning studies exhibited a broader distribution across themes, with 'resilience' and 'sustainability' being the most comprehensive urban theories applied, covering all five study themes, consistent with the results of the previous keyword co-occurrence analysis.

In Theme 1, H1N1-related studies primarily focused on national and regional pandemic preparedness plans (Mao & Bian, 2010) with a security framework for enhancing urban monitoring and risk assessment during different pandemic phases (Ben et al., 2010). Challenges included conflicting management at various levels and a lack of reliable criteria for judging pandemic phases (Purohit et al., 2018; Holmberg & Lundgren, 2018). In the COVID-19 period, studies highlighted the continued focus on city monitoring and risk assessment at the management level, emphasizing the transition from human-driven to

techno-driven urban management. The significant contribution of smart cities in urban governance was explored, indicating that techno-driven policies and actions facilitated crisis management, enhanced community well-being, maintained urban functionality, and increased city resilience (Wirtz et al., 2021; Sharifi et al., 2021).

In Theme 2, both H1N1 and COVID-19 studies involved tracking virus spread through mathematical modeling, characterizing the link between cities and pandemics, and assessing the effectiveness of environmental or social measures. While both periods focused on the effectiveness of Non-Pharmaceutical Interventions (NPIs), COVID-19 studies delved into the impact of lockdowns on cities and incorporated new technologies like artificial intelligence and digital twin.

Socioeconomic Factors (Theme 3) during the H1N1 period mainly focused on the impact of road traffic on pandemic spread, with other factors such as higher population density, income, hospitals, college students, and lower GDP per capita also associated with higher cumulative incidence. COVID-19 studies analyzed built environment factors, including building density, urban form, and city connectivity. Additionally, a focus on demographic drivers, informal labor, low educational attainment, the elderly, and ethnic minorities underscored the importance of addressing social vulnerability in pandemic recovery and future responses.

Built Environment (Theme 4) emerged as a significant factor in COVID-19 studies, supporting public health measures and reducing infection risks. Research analyzing the built environment's statistical relation to the number of confirmed cases highlighted the role of land use, commercial facilities, and transportation infrastructure. Some studies predicted changes in the built environment, suggesting potential shifts in architecture practices, civil engineering, project management, and urbanism.

In Theme 5, Post-COVID Planning, researchers explored four main directions: (1) developing a comprehensive and integrated prevention system for multi-urban disasters, (2) transforming urban space across various domains, (3) advocating for a green urban recovery path, and (4)

emphasizing smart solutions for a more inclusive, tech-led development. These aspects were interconnected, with several studies exploring more than one dimension. The post-COVID planning theme was absent during the H1N1 period.

These findings illustrate the evolution of urban planning responses during the H1N1 and COVID-19 periods, showcasing shifts in research themes and theoretical applications across various domains.

Table 2.2 Percentage and keywords of articles per study theme of the included papers.

			Occurrence of Urban Theory Keywords												
Study theme	**Group**	**Percentage (%)**	Resilience	Smart cities/city	Sustainability	Vulnerability	Healthy city	15-minute city	Compact city	Urbanism	Urbanism Temporary	Urbanism Informal	Tactical	Livable city	Weberian city
Governance policy	H1N1	57				1									1
	COVID	13	3	6	1										
Built environment	H1N1	0													
	COVID	10	2		1										
Modeling	H1N1	33													
	COVID	10	1		1		1								
Socioeconomic factors	H1N1	10													
	COVID	32	5	1	1	4			1						
Post COVID planning	H1N1	0													
	COVID	35	9	5	5	1	2	3	1	1	1	1	1		
Total	H1N1					1									1
	COVID		20	12	9	5	3	3	2	1	1	1	1		

2.4. Conclusion

A pivotal outcome of this study is the identification of urban theories instrumental in mitigating the impact of pandemics on urban planning. These include: (1) "resilience," (2) "sustainability," (3) "smart city," (4) "vulnerability," (5) "healthy city," (6) "15-minute city," (7) "tactical urbanism," (8) "temporary urbanism," (9) "informal urbanism," (10) "Compact city," (11) "livable city," and (12) "Weberian city," with the first four being the most prevalent. This partial answer to the initial question suggests that the integration of existing urban theories is the primary approach in responding to current pandemics. However, uncertainties persist regarding the adequacy of these existing theories and the potential emergence of new ones. As many urban theories already exhibit overlap, such as "resilience" and "sustainability," "resilience" and "smart cities," and "resilience" and "vulnerability," there is considerable potential to dismantle barriers between theories and construct a more comprehensive network. Ongoing research should continue evaluating the effectiveness of various urban theories in pandemic scenarios and explore mechanisms for their coordinated integration.

Another significant discovery is the transformation in urban planning's response to pandemics from H1N1 to COVID-19. This evolution is characterized by a shift from focusing on 'in' and 'pre' pandemic phases to a pronounced emphasis on the "post-pandemic" landscape. Furthermore, there has been a transition from central government leadership to multi-level co-governance, signaling a move towards collaborative decision-making across different administrative levels. Lastly, the trajectory has shifted from the prior neglect of the urban built environment to a renewed emphasis on 'healthiness' in urban planning and design. This dramatic evolution spans technological approaches and research scales. While anchored in the theoretical and technical foundations laid during the H1N1 period, there is a discernible resurgence of public health themes and a trend towards increasingly systematic, localized, and intelligent urban planning in the context of pandemics. Future recommendations for city managers, planners, and other local stakeholders include:

Strengthening Government-Led Smart City Construction: Overcoming data and management barriers, engaging in government services for the public, and fostering a new paradigm of

"co-governance" where the government and the public interact.

Utilizing Spatial Data for Health and Safety: Leveraging spatial data and analysis to develop an urban spatial health and safety information system, providing disease control departments with supplementary spatial early warning and monitoring capabilities for pandemics.

Incorporating Health Considerations in Urban Planning: Formulating principles and standards for integrating health considerations at all planning levels. This involves supporting institutional design in planning laws or industry standards, ensuring that spatial health and equity considerations become integral requirements in urban planning.

Chapter 3: The impact of COVID-19 pandemic on Neighborhood planning

3.1 Introduction

Historical evidence from past pandemics indicates that the built environment possesses a remarkable capacity for evolution in the aftermath of crises (Chang, 2020). Looking back to the 14th century, the bubonic plague prompted cities to clear overcrowded living spaces and innovate early isolation facilities (Lubell, 2020). The 19th-century outbreaks of typhoid and cholera played a pivotal role in the establishment of sewage and water systems, crucial for combating pathogens and leading to significant sanitary advancements (Budds, 2020; Klaus, 2020; Wainwright, 2020).

Moving into the 20th century, Europe witnessed the creation of numerous parks, promenades, and squares in response to the Spanish flu, marking early efforts to provide safer urban spaces (Grant J, 2020). The era of tuberculosis sparked a revolution in modern architecture, where traditional building forms were deemed unhealthy, paving the way for pure forms, simple geometric shapes, and the use of modern materials. More recently, during the SARS period, improvements were made to ventilation and drainage systems in local buildings, particularly in specific Asian regions such as Hong Kong (Wong et al., 2009).

However, it is widely acknowledged that the evolution of the built environment is a gradual process, often spanning several years for the transformation of building layouts and infrastructure to occur (Sartorio et al., 2021). This raises the question: How can we enhance our capacity to respond to pandemics and bolster resilience in the built environment within a shorter timeframe?

In contrast to macro-scale city measures, implementing changes in people's behavior is notably more feasible, yet equally critical, albeit less overt (Legeby et al., 2022). The widespread adoption of masks, the enforcement of social distancing, and the temporary

closure of public spaces during the COVID-19 pandemic have profoundly altered daily lives (Askarizad & He, 2022; Florida et al., 2021; Moreno et al., 2021; Feng et al., 2021). These behavioral shifts are quietly reshaping the urban landscape in a direction conducive to limiting the spread of the virus, showcasing the intricate interplay between behavior and space (Megahed & Ghoneim, 2020; Mouratidis & Yiannakou, 2022). Exploring the impact of changing lifestyles on the built environment or how the built environment responds to these lifestyles is crucial for understanding the potential for a more resilient urban morphology.

But empirical studies compiling such evidence remain limited, primarily focusing on short-term changes during the outbreak. Furthermore, lifestyle alterations are contingent on regional economic and cultural factors, influenced by policy instructions at different pandemic stages. To address this gap, this article relies on local case studies, examining the long-term dynamic relationship between people's lifestyles and the residential environment in the post-pandemic era. The paper addresses two key research questions: (1) How residents' lifestyles have changed after the pandemic? (2) How neighbourhoods have responded/adapted to these changes, identifying whether it offers opportunities for future directions in strengthening community resilience?

3.2 The material and methods

Wuhan, the city selected for this case study, is situated in central China and is home to a population exceeding 11 million residents. Being the first city to witness a COVID-19 outbreak and undergo a lockdown lasting over two months, it serves as a pertinent case for scrutinizing the repercussions of the post-pandemic lifestyle. Consequently, three sequential steps were undertaken from October 2020 to October 2022, encompassing (1) the identification of lifestyle changes, (2) the observation of neighborhood transformations, and (3) the analysis of the attributes of these changes, predicting which alterations are shaping future settlement development. In the first step, a quantitative analysis was employed, utilizing data collected through online questionnaires. The subsequent steps, involving qualitative analyses, incorporated behavior diaries, investigative surveys, and workshops. The diagram illustrated in Figure 3.1 further elucidates the interconnections among these steps and

the overarching research objectives.

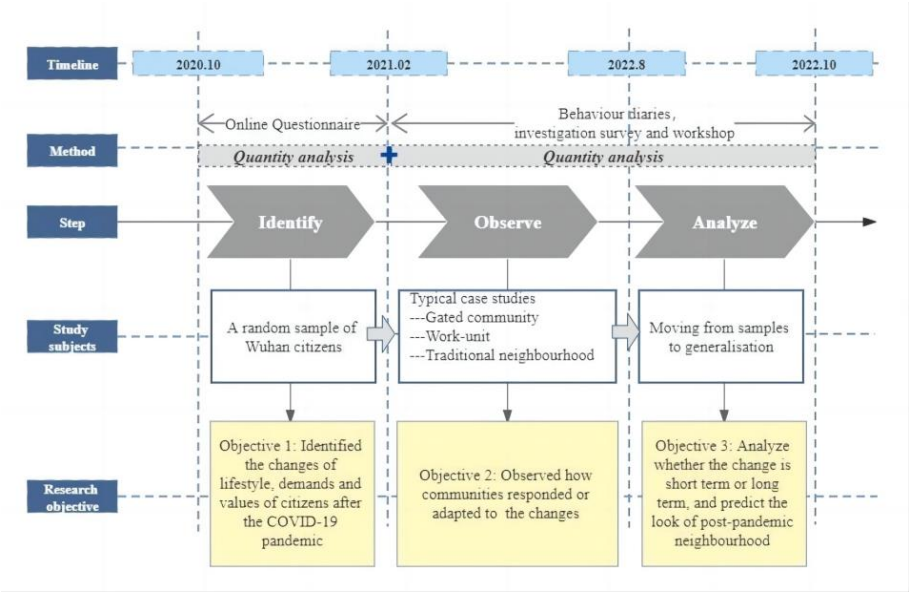


Fig 3.1 Flowchart of the research (*Source from the authors*)

3.2.1 Quantity analysis: Online questionnaire

The research commenced in October 2020, approximately six months after the official unsealing of Wuhan (Liu et al., 2020). The initial phase involved conducting an online questionnaire survey through the "Wenjuanxing" platform. The primary focus was to identify potential changes in the lifestyles, demands, and values of Wuhan citizens following the COVID-19 pandemic. Employing snowball sampling via social networks, most questionnaires were distributed across 63 WeChat groups covering a wide range of topics, including childcare, travel, language study, cooking, sports, and local issues in Wuhan. Sociodemographic variables such as gender, monthly income, and education level were considered to ensure a diverse participant pool. By February 2021, the final sample comprised 949 individuals aged 18-83 years. The sample included 432 citizens from Hankow district, 201 from Hanyang district, and 316 from Wuchang district, encompassing various residential areas across Wuhan.

The questionnaire framed questions in a comparative manner, providing respondents with the following guidelines: "Please think about your life after the COVID-19 pandemic (right now) vs. Please think back to your life before the COVID-19 pandemic (before December 2019)."

In this context, an evaluation of citizens' lives before and after the pandemic, covering aspects of food, housing, transport, health, shopping, and entertainment, was conducted. For questions related to demands and values that defy precise description or measurement, a 1 – 5 Likert scale was employed. Participants used the scale to specify the importance of the presence of certain public spaces (e.g., from 1: "not at all" to 5: "a great deal") or the frequency of engaging in an online activity (e.g., from 1: "never" to 5: "everyday").

3.2.2 Quality analysis: Behaviour dairies, investigation survey and workshop

The second phase of the study commenced in February 2021, marking a year since the initial emergence of the coronavirus in Wuhan. For this step, three distinct neighborhoods—Vanke, Gonglu, and Eryao community—were selected for observation, each representing a primary type of Chinese settlement: gated-community, work-unit, and traditional neighborhood, respectively (Wu, 2022). Over a span of eighteen months, meticulous recording of every subtle change was undertaken, primarily through three main channels: volunteers' behavior diaries, regular interviews with residential committees, and monthly field investigations.

A total of 25 volunteers from all three neighborhoods participated in the "Behavior Diaries" project. Each individual was tasked with noting interesting findings in their respective neighborhoods on a weekly basis. Special attention was given to the interactions between their own behaviors, those of their neighbors, and the settlement environment. This encompassed preferred stopping places, favorite socialization spots, and locations where physical activity was frequently undertaken, among other details. The "Behavior Diaries" served as a valuable means of documenting information that would typically be challenging for researchers to access, including details of life that are rarely observed or pertain to hard-to-reach private spaces (Mascatelli et al., 2021).

In addition, crucial insights were gleaned through periodic exchanges with neighborhood committees, which possessed first-hand information about community constructions. As a complementary approach, adopting an 'outsiders' perspective, researchers conducted monthly field investigations of the three neighborhoods. This involved utilizing photographs,

measurements, interviews, and other components of site mapping to gather comprehensive data.

For the final step, a collaborative workshop, recognized as an effective model for community participation in urban regeneration (Li et al., 2020; Pelzer et al., 2015), was employed. In late August 2022, offline workshops were conducted for each neighborhood, involving representatives of property owners, property staff, personnel from settled enterprises, and officers from the residential committees. The primary objective was to validate the accuracy of every item on the change list compiled over the eighteen months and analyze the driving forces behind these changes.

In September 2022, the original teams from all three neighborhoods reconvened online, joined by planning experts. The focus of the discussion encompassed the impact of lifestyle changes on the neighborhoods, the effective adaptation strategies employed by the neighborhoods, and potential future trends for resilient neighborhoods. The outcomes of this segment are presented in Section 3.2. All data was gathered and information synthesis was carried out manually using an inductive content analysis method (Ahuvia, 2001), extracting comprehensive insights from fragmented information. Changes in neighborhoods were categorized by type and scale, as summarized in Table 1.

3.3 The results of empirical study

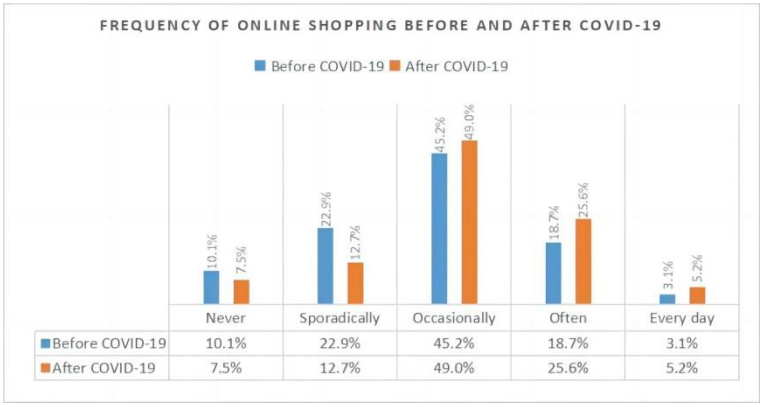
3.3.1 Lifestyle changes (General situation)

The questionnaire data identified the following three main changes in citizens' lifestyles when comparing pre-pandemic and post-pandemic situation.

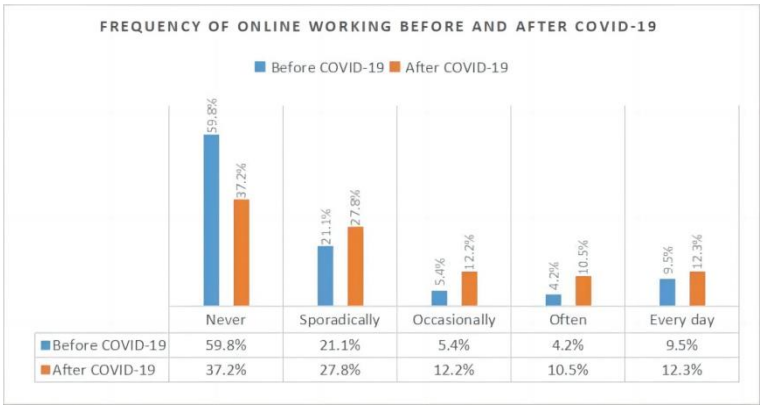
Change-1: Strengthening trend towards online activities

All online activities, including shopping, working, learning, and entertainment, as covered in the questionnaire, exhibited an increase compared to the pre-COVID-19 period. Figure 3.2 provides a detailed comparison of the frequencies of online activities. The most substantial

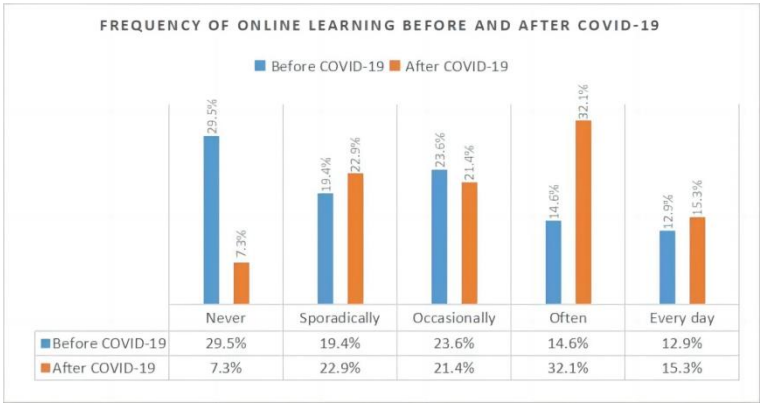
changes occurred in online learning and working. Of the respondents, 29.5% and 59.8% stated they had never worked and learned online before COVID-19, which dropped sharply to 7.3% and 37.2%, respectively, afterward. While online shopping and online entertainment were already popular among respondents before COVID-19, the growth in frequency of use was not as pronounced as that observed in online working and learning. It's worth noting that, considering 13.5% of participants were from the 65+ age group and did not regularly use electronic devices, the questionnaire was separately analyzed for this senior group. It was discovered that among this group, those who chose the "sporadically" and "occasionally" options for online shopping surged to 213% of the pre-COVID-19 levels. This underscores the notion that elderly citizens, especially those living alone, found it challenging to navigate extreme pandemic conditions without internet access (Liu et al., 2020). In a broader sense, COVID-19 transformed the online lifestyle from being a luxury to a necessity.



	Never	Sporadically	Occasionally	Often	Every day
Before COVID-19	10.1%	22.9%	45.2%	18.7%	3.1%
After COVID-19	7.5%	12.7%	49.0%	25.6%	5.2%



	Never	Sporadically	Occasionally	Often	Every day
Before COVID-19	59.8%	21.1%	5.4%	4.2%	9.5%
After COVID-19	37.2%	27.8%	12.2%	10.5%	12.3%



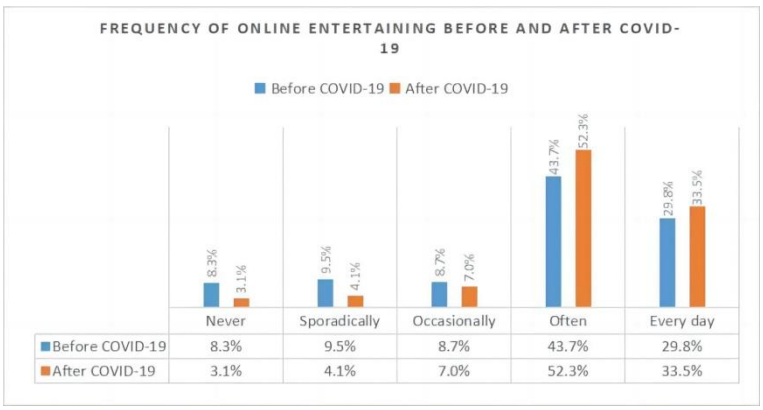


Fig 3.2 Frequency of online activities before and after COVID-19. Note: sporadically= less than once a month; occasionally= sometimes a month; often= sometimes a week. Online working and learning were analyzed only for those with jobs or students among participants (N = 755). Sampling of other activities was complete (N = 949) (*Source from the authors*)

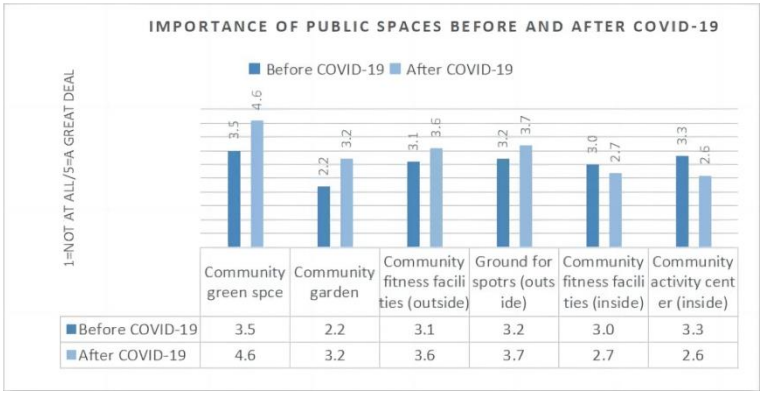
Change-2: Expanding demands for green and outdoor spaces

Figure 3.3 illustrates that the perceived importance of community green spaces, community gardens, outdoor community fitness facilities, and outdoor sports grounds all increased after COVID-19. On average, community green spaces were identified as the most important public spaces both before and after COVID-19, followed by outdoor sports grounds. A substantial rise in importance was observed for community gardens, indicating a 45.5% increase, while the increase in the perceived importance of outdoor community fitness facilities was comparatively smaller, showing a 16.1% increase.

The surge in popularity of community gardens following the COVID-19 outbreak could be attributed to concerns about food shortages during the lockdown. The questionnaire results revealed that 17.1% of respondents cultivated plants, including vegetables, on their balconies

or terraces, and 6.7% attempted plant cultivation for the first time after COVID-19, reflecting a heightened enthusiasm for gardening.

Conversely, the importance of indoor community spaces, such as community activity centers (inside), experienced a marked reduction (26.9% decrease). A similar decrease (11.1% reduction) was noted for indoor community fitness facilities. The heightened importance of outdoor public spaces was paralleled by a decline in the significance of indoor public spaces. In summary, the results indicate a preference for outdoor and green public spaces in the post-COVID-19 era.



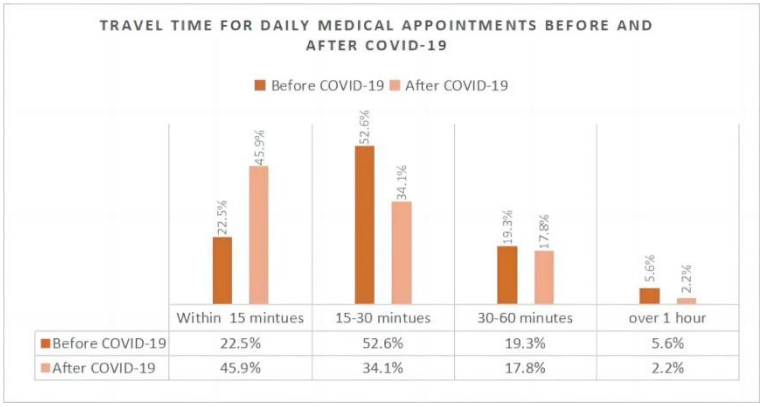


Fig 3.3 (top) Mean values of importance of spaces before and after COVID-19 **Fig 3.4** (bottom): Travel time for medical appointments before and after COVID-19(*Source from the authors*)

Change-3: Proximity choices in daily activities

Despite the questionnaire research being initiated six months after Wuhan lifted its lockdown and the entire city was gradually returning to normalcy, the data revealed a significant narrowing of people's daily travel ranges. As depicted in Figure 3.4, before COVID-19, 52.6%

of respondents sought medical treatment within a travel time of 15-30 minutes. After the pandemic, this proportion decreased to 34.1%, and almost half of the surveyed individuals (45.9%) chose to travel within 15 minutes for medical appointments. Similar trends were observed for offline shopping, dating, dining, and weekend trips, indicating a shift towards proximity in various aspects of daily life.

3.3.2 Neighbourhood responds

Over the course of a year and a half of observation, changes were identified in all three neighborhoods, primarily concentrated at the microscopic scale, involving 'soft' adjustments. Following thorough verification and discussions with various stakeholders, the exact locations of these changes in each settlement are depicted in Figure 3.5. The changes spanned the ground floor layer, roof layer, and outdoor layer, showcasing a remarkable consistency among the three neighborhoods.

In terms of the range of changes, there was a notable convergence, with a collective addition of 4 logistics stations, 1 expanded waterfront green space, 2 roof gardens, 9 sports grounds, 21 small shops, and 7 informal public spaces. Additionally, 15 instances of self-renovation of houses were discovered, providing insights into how settlements rapidly responded and adapted to evolving lifestyles. Table 3.1 attempts to catalogue the built environmental changes across all samples.

Fig 3.5 Maps showing the locations of changes of Vanke, Gonglu and Eryao communities (*Source from the authors*)

Ground floor Layer: Rapidly emerging logistics stations and inner commercial street

With the widespread adoption of online lifestyles among residents, particularly the significant surge in online shopping during COVID-19, the practice of 'contactless delivery' has become prevalent. 'Contactless delivery' involves logistics personnel delivering goods through smart parcel lockers, posthouses, or user-designated locations, thus avoiding direct contact with the recipient. This trend has led to the emergence of numerous new logistics spaces.

Between March 2021 and September 2022, a total of 9 additional smart lockers were installed on the ground floor of residential buildings across the three neighborhoods (refer to Fig 3.6 and 3.7). The integration of these logistics spaces into living areas also spurred the development of community businesses. In the Gonglu residential area, a noteworthy case was identified where an owner rented out their garage as a courier house. Subsequently, similar garage rentals proliferated in the surrounding area, leading to the gradual formation of an internal shopping street within a year (see Fig 3.8). Despite the widespread closure of brick-and-mortar businesses, this internal commercial street was notably vibrant. The variety of stores, primarily based on the online-to-offline (O2O) business model, expanded to include food, restaurants, clothing, beauty salons, and wellness establishments. This evolution attracted a growing number of regular consumers, representing a response to the trend of localizing residents' daily activities.



Fig 3.6-7 touchless smart lockers(left+middle) **Fig 3.8** Inner commercial street transformed from garages(right) (*Source* Photo taken by the authors)

Roof layer: Sky Garden and children's games

House renovations were commonly observed, particularly in low-rise and multi-story buildings. The focal point of these renovations was on outdoor or semi-outdoor spaces, such as balconies, terraces, and front yards (refer to Fig 3.9). Beyond just reopening sealed balconies, the renovations included enlarging the area, adding outdoor furniture, and introducing more greenery.

In the case of high-rise buildings, concentrated and larger-scale green spaces emerged as roof gardens (see Fig 3.10), with two newly opened gardens measuring 286 square meters and 115 square meters found in Vanke and Gonglu Community, respectively. These rooftop gardens predominantly cultivated vegetables, including tomatoes, lettuce, cucumbers, and spring onions. Residents in the same building initiated and collectively maintained these gardens. Each household was allocated an area of approximately 3m*3m, and the harvested produce was shared among the residents. New residents consistently joined the rooftop planting initiative, leading to ongoing growth throughout the observation period. Additionally, aside from serving as a haven for gardeners, the roof spaces transformed into playgrounds for children. A volunteer's observation diary in Er Yao community noted, "on 18th June 2021, I found children meeting up to play on the roof terrace for the first time." Similar occurrences were subsequently reported in the other two samples (see Fig 3.11).



Fig 3.9 Roof additions(left) **Fig 3.10** sky garden(middle) and **Fig 3.11** children’s games(right)

(*Source* Photo taken by the authors)

Outdoor Layer: Thriving public space

With residents more closely tied to their immediate surroundings, public spaces have gained increased significance. Bottom-up interventions were evident across all communities, with residents reclaiming spaces to create playgrounds for children, socialize, and exercise. This resulted in a series of 'spatial magic,' including street corners repurposed with mobile furniture, greenbelts transformed into campsites, and tai chi areas set up in parking lots (see Fig 3.12). In most cases, the fundamental properties of these spaces remained unchanged, with adjustments primarily focused on the allocated time for use. While rare exceptions existed, as demonstrated by the transformation of car parks into public spaces in both the Er Yao and Vanke communities (Fig 3.13).Apart from grassroots efforts to secure space, there were proactive interventions at the management level by residential committees. For instance, in the Gonglu community, substantial unused space was repurposed and designated as public areas. Outdoor play facilities for children were introduced into vacant spaces, and various corner plots were painted and repurposed into badminton or basketball courts (Fig 3.14). Consequently, a sufficient number of outdoor activity venues for residents were established in a relatively short timeframe.




Fig 3.12 tent setters on greenbelt(left) **Fig 3.13** Transformation from parking lot to public plaza(middle) and **Fig 3.14** new badminton court(right) (*Source* Photo taken by the authors)

Table 3.1 Change list of Vanke, Gonglu and Eryao communities from Feb.2021 to Oct.2022

Spatial dimension	Specifics of the changes	Neighbourhood in which it appeared	Earliest emergence	Subjects of participation	Corresponding changes	Long term(L) VS Short term(S)	Qualities supporting public health in pandemic
Ground floor	Increase of touchless smart lockers	1/2/3	2021.5	Property; Enterprise	1	L	Encourage contact-free behaviour to reduce the spread of the virus
	Increase of posthouses	1/2	2021.4	Self-employed	1	L	
	Increase of temporary tables or shelves at the entrances when the community was closed	1/2/3	2021.7	Property	1	S	
	Garage rental to commercial tenants, being transformed into various small shops(haircut/bakery/milk station...)	1/2	2021.8	Owners; Self-employed	3	S	
Roof	Addition of terrace or roof layer	1/3	2021.3	Owners	2	S	
	Added sky garden	1/2	2021.4	Owners	2	L	
	Rooftop playground for children	1/2/3	2021.6	Owners	2/3	S	
Outdoor	Parking lot transformed into public space	1/3	2022.3	Owners	2	S	Physical and mental health benefits
	Increase of outdoor sports venues (ping pong table/basketball hoop/badminton court...)	1/2	2022.1	Property; Residential committee; Enterprises	2	L	
	Neighbour chatting or chess and cards with mobile furniture	1/2/3	2021.4	Owners	2	S	
	Tent setters appear on the greenbelt	1	2022.3	Owners	2/3	S	

Note: Neighbourhood 1= Vanke 2=Gonglu 3=Eryao, Change 1=Strengthening trend towards online activities 2=Expanding demands for green and outdoor spaces 3=Proximity choices in daily activities.

3.4 Conclusion

This study was carried out during a period when the pandemic in Wuhan was relatively calm under China’s zero-Covid-19 policy, using empirical cases to examine the 'post-pandemic' impact. Special attentions were paid to exploring how the neighbourhoods responded to the changing lifestyle of residents and made adaptions to limit the spread of the virus on the one hand, and to improve life quality maintaining physical separation on the other hand.

The rising prevalence of online lifestyles, coupled with an increased desire for outdoor spaces and the temporary constraints on movement, positions neighborhoods as a pragmatic, adaptable, and cost-effective solution for rapid adjustment. Our observations in Wuhan reveal the implementation of 'contactless delivery,' the infusion of greenery within residential enclaves, and the emergence of public spaces—all achieved without resorting to extensive demolitions or reconstructions. Instead, these changes manifest as subtle, micro-adjustments, stemming from the necessity to adapt to a novel way of life. Through these transformations, we catch a glimpse of the potential role of urban design and utilization in expediting recovery and crisis readiness across diverse contexts. This includes the prospect of embedded development for "third-party" spaces, the creation of self-sufficient and self-organizing structures adaptable to various scenarios, and the activation or transformation of public ownership. Significantly, these grassroots interventions foster connections among individuals, bridging the gaps between home and public spaces, indoor and outdoor realms, thereby fortifying community resilience through interpersonal networks of trust. The impact of COVID-19 extends beyond the physical realm, profoundly altering both material and emotional landscapes. The redesign and reorganization of spaces serve not only functional purposes but also act as therapeutic platforms, aiding individuals in healing from shared experiences. This underscores a poignant reminder of the heightened significance of communal living in our current landscape.

The two-year research period following the outbreak in Wuhan represents just the initial phase; understanding lifestyle changes during crises requires more prolonged and in-depth observation. As we anticipate an extended coexistence with the new coronavirus, there is an

opportunity to scrutinize the intricate relationship between the urban fabric and the behavior of city dwellers within the constraints of challenging circumstances.

Recognizing that each city undergoes distinctive lifestyle changes influenced by its socioeconomic context, there is a substantial divergence in the strategies for environmental adaptations. Further investigation is imperative to delve into the dynamic interplay between behavior and space across diverse local communities. This collective exploration will contribute significantly to advancing our comprehension of healthy urban planning and design approaches, ultimately providing valuable insights for future challenges and crises.

Chapter 4: An integrated assessment framework for post-pandemic neighborhood

4.1 Introduction

The COVID-19 pandemic provides an opportunity to rethink the role of cities, their spaces, the allocation of resources, and the patterns in which socioeconomic activities are carried out, with possible changes brewing in all areas. Given its role in the physical and functional structure of human settlements, urban planning is a key factor in shaping an optimal future for cities. Its historical roots further emphasize this importance (Wang, 2021). Sustainability, resilience, smartness, inclusiveness, decentralization (Tu & Reith, 2023), a series of paradigm discussions have created new requirements for creating healthier communities in the post-pandemic era. While residents reflect dramatic changes during and after the pandemic (Mouratidis & Papagiannakis, 2021), which include sub-urbanized migration, housing renovation, changing modes of travel, enhanced demand for blue-green spaces, increased frequency of use of public open spaces and outdoor venues, further expanded online lifestyles, and proactive participation in community and local affairs, etc., which all offer crucial clues and insights into neighborhood planning for preventing and mitigating future pandemics, while suggesting the potential shifts in principles and standards governing the physical and functional organization of neighborhoods.

To this day, there are numerous studies examining the impact of pandemics on urban planning. Frumkin (2021) argues that pandemics offer a historic opportunity to firmly ground placemaking in human needs, justice, and environmental sustainability, with the promise of healthier cities than ever by improving the efficiency and fairness of urban governance and utilizing emerging technologies. Mouratidis (2021) synthesizes early insights into how COVID-19 is reshaping the relationship between cities and quality of life. The possible impacts of various physical elements of cities on quality of life across domains such travel, leisure, work, social relationships, resident well-being, emotional responses, and health during COVID-19 are presented, as well as potential ways in which cities can be linked to these

domains of life. Jevtic et al., (2022) emphasize the short-term impacts of pandemics on cities and highlight urban planning solutions that can have positive effects on public health. In addition to this, there is also a lively debate about "new" urban models influenced by the crisis, such as mega-neighborhoods, low-traffic neighborhoods, X-minute cities, and car-free cities and neighborhoods. What these new models have in common is a reversal of planning that prioritizes the automobile in favor of walking and cycling (Nieuwenhuijsen 2021). In parallel with changes in transportation modes, new changes are also reflected in localized services and facilities. The 15-minute city, for example, intends to bring activities to the neighborhood rather than people to the activities, thus restoring the notion of proximity in urban planning. Local decentralization of a large number of services and facilities is advocated to balance the differences between the city's districts (Pozoukidou and Chatziyiannaki, 2021). In quantitative research, Lak et al., (2021) developed a comprehensive indicator framework and computed resilience scores based on different neighborhoods in Tehran, Iran. Arvin et al., (2023) assessed community vulnerability in Ahvaz, Iran, using nine indicators. Mercader et al., (2021) selected 32 indicators across building, urban, environmental, and social dimensions to build an assessment model identifying vulnerable areas in the evolving contexts of Mexico and Spain. Together, these studies reveal substantial variations in pandemic resilience across urban communities, highlighting issues of socioeconomic justice.

Although current studies shed light on the association between neighborhoods and COVID-19, there are still gaps to be addressed. Firstly, most research has focused on the short-term effects of the pandemic on neighborhoods during its outbreak, such as improvements in environmental quality and changes in residents' commuting patterns. However, there is a dearth of research investigating the more enduring changes that persist beyond the initial trajectory of the pandemic. Given the prolonged normalization of the pandemic, there is a need for systematic reviews as evidence becomes more comprehensive and mature. Secondly, while some studies have explored post-pandemic neighborhood models and evaluation systems, they are often confined by outdated planning and design attributes and frameworks. Using outdated indicators to address new issues fails to capture variables reflecting

post-pandemic environmental changes and evolving lifestyles.

To bridge these gaps and gain a deeper understanding of the lasting impact of the COVID-19 pandemic on neighborhoods, this study first sought clues from the literature since the outbreak to identify long-term factors that influence health outcomes from a post-pandemic perspective. Secondly, these factors are used to build an integrated assessment framework for post-pandemic neighborhood to help quickly identify vulnerable urban areas and fully prepare for the next pandemic.

4.2 Methodological approach

The development of a comprehensive set of indicators is recognized as an accurate method for assessing the health of neighborhoods. However, the pandemic has brought about many changes in multiple dimensions and aspects. How to select appropriate indicators and how to combine them to provide a comprehensive measure of a complex multidimensional phenomenon? This study considers parsing according to the following three phases (see in Figure 4.1). And the findings of these three phases will directly correspond to the following sections in 4.3, 4.4, and 4.5.

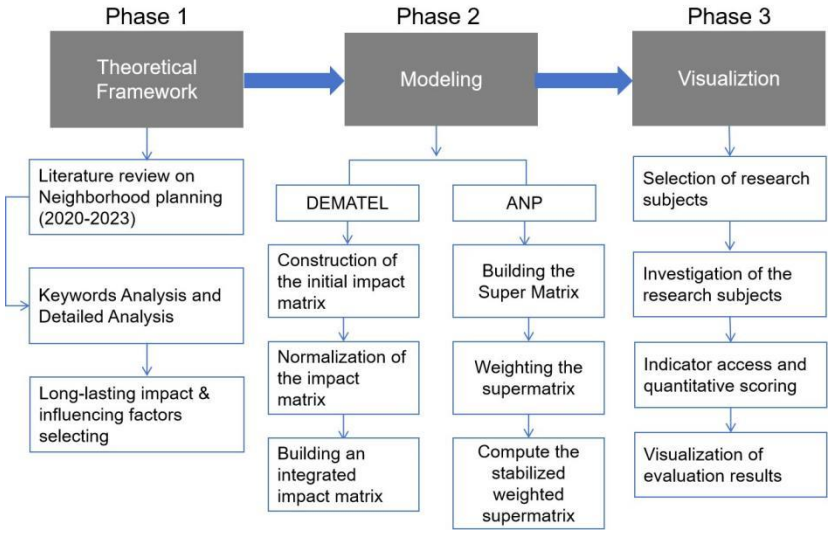


Fig 4.1 Flowchart of building assessment framework for post-pandemic neighborhood (*Source from the authors*)

4.2.1 *Phase 1*：Theoretical framework for indicator selection

The development of composite indicators should begin with a study and review of relevant literature and theoretical frameworks. This will contribute to the elaboration of concepts and clarify the structure of the analytical framework.

4.2.1.1 Literature collection and survey

To achieve the objectives of this research, the study employed the databases including Web of Science (WOS), Scopus and PudMed. The search spanned from 2020 to 2023, with a restriction to English language. Moreover, document types were confined to peer-reviewed articles and reviews from well-known academic publishers. Further, this study adopted searching mode in keywords combination: TITLE-ABS-KEY (‘COVID-19’ OR ‘coronavirus’ OR ‘pandemic’) AND (‘neighborhood’ OR ‘community’ OR ‘settlement’) AND (‘planning’ OR ‘design’). Given that a significant portion of the results were derived from public health medicine, the research focus was narrowed down to four areas: urban studies, environmental studies, social science and geography. Notably, after the initial search across the aforementioned three databases, there may still be relevant papers published in connection with this study. To address this, alerts were activated on all data platforms to regularly receive the latest information on relevant paper publications, ensuring the continuous integration of their insights into this study.

The initial literature search was conducted in June 2023, and a total of 1479 articles were retrieved. The study initially screened the titles and abstracts of each paper, applying exclusion criteria as follows: (1)“pandemic-related”words only appeared in the abstract but the study itself was non pandemic-related. (2) papers not related to neighborhood planning (e.g., real estate economy or pedagogy). (3) papers not at the neighborhood-scale (e.g., city-scale or building-scale). (4) researches not situated in an urban area. After eliminating irrelevant and overlapping papers, only 247 were left. Following this, the authors carefully examined the remaining articles with the aim of extracting relevant information related to neighborhood health influenced by the pandemic. During this full-text review, 82 articles

were further excluded due to a lack of detailed information on health outcomes or factors influencing neighborhoods. Finally, a total of 165 target articles were studied in detail in this research.

4.2.1.2 Data Analysis

The following two methods were employed to generate the required results: keywords analysis and detailed analysis. The keywords analysis helps to understand the evolution and trends of neighborhood under the influence of pandemic throughout the years, while the detailed analysis aid in assessing of the relationship between the various influencing factors and the health outcomes.

---Keywords analysis

Keywords serve as fundamental components in research concepts, methodologies, and themes. Utilizing co-occurrence keyword analysis aids in swiftly identifying research hotspots and the evolutionary characteristics of neighborhood planning influenced by the pandemic. To conduct keywords analysis, the study utilized the tool CiteSpace 6.2.R6. It stands as an information visualization tool developed in Java, enabling exploration of knowledge clustering and distribution within citation spaces based on relationships between cited and citing literature (Chen, C, 2006). This software facilitates collaborative and co-occurrence analysis functions for various aspects like author, institution, and country cooperation networks, as well as the analysis of keyword and subject term co-occurrences. In the context of this paper, the focus was on employing keywords co-occurrence timeline and keywords burst detection.

With the help of CiteSpace tool, keywords are grouped into clusters based on their collaborative networks and chronologically arranged on the timeline according to their earliest appearance. Once a keyword emerges, it remains fixed in the year of its initial appearance. While it continues to appear in subsequent papers, it is displayed solely in the year of its first appearance. Each year on the timeline graph represents new keywords that have emerged, connected by lines if they co-occur in the same paper as the previous keywords.

This results in an increase in frequency and node size by one circle for the earlier keywords. Keywords that bridge past and future research developments are denoted with an outer circle in purple. Hence, significant emphasis is placed on the largest nodes and these pivotal points, highlighting hotspots and the developmental history of the research field (Chen & Song, 2019). Besides, the use of keyword burst detection reflects research areas with significant influence over a period, pinpointing when a keyword emerged and its ongoing activity (Moldavska & Welo, 2017). This approach provides a clear picture of research trends in neighborhood planning over the years and aids in discerning the ongoing, enduring impacts of the pandemic.

---Detailed Analysis

Detailed analysis used to make an assessment of the relationship between the various influencing factors and the health outcomes, as well as the identification of what are the potentially major influencing variables in the long run. To achieve this, this study produced information extraction table in Microsoft Excel to collect relevant evidence, including research dimension, neighborhood risk factors, impact on specific health outcomes, main changes after the pandemic, and suggestions for future neighborhood planning. Given the heterogeneity in the classification of health outcomes, this study uses UN Habitat's model (UN-HABITAT, 2020) to classify the possible impact of planning on health into physical health, mental health, and health equity. While neighborhood research dimension and risk factors were analyzed through the inductive content analysis method (Mayring, P., 2014). Inductive content analysis, as discussed by Ahuvia, A (2001), is favored when existing knowledge on a specific topic is fragmented and lacks systematic review. This approach allows for a more comprehensive extraction of insights without biases or preconceived assumptions (In this study, it implies the absence of a priori assumptions regarding influencing factors and their collective health impacts on post-pandemic neighborhood).

For each neighborhood risk factor–health outcome pair in the included reviews, the main findings were summarized and graded into four types: ‘positive,’ ‘negative,’ ‘null,’ and ‘inconsistent’. The designation of positive indicated a favorable impact of neighborhood

factors on health outcomes, while negative denoted the opposite. Null referred to the absence of observed associations between the neighborhood risk factor and the health outcome. Inconsistent signified that individual studies in this systematic review did not provide consistent conclusions about the relationship between the risk factor and outcome.

4.2.2 *Phase 2*：Framework modeling

The next stage is to identify appropriate indicators and conduct factor analysis to determine the correlation between the indicators and to find out the relationship in between.

Due to the ambiguity of evaluation factors, Decision Laboratory Analysis (DEMATEL) is employed to obtain the comprehensive impact matrix and network relationship model in order to improve evaluation accuracy. This will effectively illustrate the internal structure of the system and clarify the influence relationships between various factors. Meanwhile, the use of Analytic Network Process (ANP) can objectively describe the characteristics of interactions and mutual influences among various factors in the evaluation system, making the obtained indicator weights more objective compared to the traditional Analytic Hierarchy Process (AHP) method. Therefore, this study proposes a method for establishing a post-pandemic neighborhood health evaluation system based on DEMATEL and ANP.

4.2.2.1 DEMATEL

DEMATEL employs graph theory and matrices for systematic analysis, calculating the strength of mutual influences among indicators to reveal the interrelationships between various evaluation indicators within the system. The specific calculation steps are as follows:

Step 1: Construct the initial direct impact matrix, M_D. Identify factors included in the system for the research problem, denoted as U_1, U_2, ..., U_N. Select relevant scales and design survey questionnaires. Survey respondents assess the impact relationships between indicators and determine the degree of direct influence between indicators through pairwise comparisons. After averaging all respondent ratings, construct the initial direct impact matrix M_D. The matrix element d_{ij} represents the degree of influence of indicator U_i on indicator U_j. When i=j,

d_{ij}=0, then:

$$\boldsymbol{M}_D = \begin{bmatrix} 0 & d_{12} & \cdots & d_{1i} & \cdots & d_{1N} \\ d_{21} & 0 & \cdots & d_{2i} & \cdots & d_{2N} \\ \vdots & \vdots & & \vdots & & \vdots \\ d_{i1} & d_{i2} & \cdots & 0 & \cdots & d_{iN} \\ \vdots & \vdots & & \vdots & & \vdots \\ d_{N1} & d_{N2} & \cdots & d_{Ni} & \cdots & 0 \end{bmatrix} \qquad (1)$$

Step 2: Normalize the direct impact matrix. The standardized direct impact matrix, M_N, is obtained from Formula (2).

$$\boldsymbol{M}_N = \frac{\boldsymbol{M}_D}{\max[\max_{1 \le i \le N} \sum_{j=1}^{N} d_{ij}, \max_{1 \le j \le N} \sum_{i=1}^{N} d_{ij}]} \qquad (2)$$

Step 3: Construct the comprehensive impact matrix, M_T. Based on the standardized direct impact matrix, M_N, calculate the comprehensive impact matrix, M_T, using Formula (3).

$$\boldsymbol{M}_T = \lim_{k \to \infty} (\boldsymbol{M}_N + \boldsymbol{M}_N^2 + \cdots + \boldsymbol{M}_N^k) = \boldsymbol{M}_N (I - \boldsymbol{M}_N)^{-1} \qquad (3)$$

Where I represents the identity matrix.

Step 4: Set the threshold value to obtain the modified comprehensive impact matrix, M' $_T$, calculate the centrality and causality of indicators, and draw the network relationship model. Considering the actual situation of the evaluation objects, set the threshold value. If the value of element t_{ij} in the comprehensive impact matrix M_T is less than the threshold, it indicates that there is no strong influence relationship between indicator U_i and U_j. In this case, assign its value to 0 to obtain the modified comprehensive impact matrix, M' $_T$. According to Formulas (4) and (5), calculate the sum of rows and columns of M' $_T$ separately to obtain the centrality, r, and causality, c. The sum of (r+c) represents the total degree of influence and being influenced between indicators, referred to as centrality. A higher centrality indicates stronger mutual relationships between indicators. The difference of (r-c) represents the degree of causality between indicators, referred to as causality. If the causality is a positive value, it indicates that the indicator has a greater influence on other indicators, known as a causal

element. If the causality is a negative value, it indicates that the indicator is more influenced by other indicators, known as a resultant element.

$$r=\left[\sum_{j=1}^{N} t_{ij}\right]=(r_i)_{N*1}=(r_1,\cdots,r_i,\cdots,r_N) \qquad (4)$$

$$c=\left[\sum_{i=1}^{N} t_{ij}\right]=(c_j)_{1*N}=(c_1,\cdots,c_j,\cdots,c_N) \qquad (5)$$

In summary, the indicator network relationship model can be drawn, providing a basis for constructing the network hierarchy structure using the ANP method. Additionally, this model can clearly display the influence relationships between various indicators within the system.

4.2.2.2 ANP

The ANP improves upon the AHP by addressing the interactions and mutual influences among internal elements within the evaluation object system. Through the ANP method, the internal structure of the system can be accurately described, resulting in more objective and realistic assessment indicator weights. The steps for implementing the ANP method are as follows:

Step 1: Construct the supermatrix. Respondents use a scale of 1 to 9, where the scale meanings range from equally important to extremely important. They assess the elements within the element group through pairwise comparisons to construct the supermatrix. Initially, using the control layer elements as criteria, and considering the network layer element group U_j (j = 1, 2, ..., N), the elements U_{jl} (l = 1, 2, ..., N_j)as sub-criteria, compare the elements in element group U_i with U_{jl} one by one to obtain the supermatrix W_{ij}.

$$W_{ij}=\begin{bmatrix} w_{i1}^{(j1)} & w_{i1}^{(j2)} & \cdots & w_{i1}^{(jn_j)} \\ w_{i2}^{(j1)} & w_{i2}^{(j2)} & \cdots & w_{i2}^{(jn_j)} \\ \vdots & \vdots & & \vdots \\ w_{in_i}^{(j1)} & w_{in_i}^{(j2)} & & w_{in_i}^{(jn_j)} \end{bmatrix} \qquad (6)$$

Where the column vector W_{ij} represents the ranking vector of the degree of influence of the

elements U_{i1}, ..., on the elements U_{j1}, ... in U_j. If the elements in U_j are not influenced by the elements in U_i, then W_{ij}=0. Thus, the supermatrix W under the criteria of the control layer is obtained as:

$$W = \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1N} \\ W_{21} & W_{22} & \cdots & W_{2N} \\ \vdots & \vdots & & \vdots \\ W_{N1} & W_{N2} & \cdots & W_{NN} \end{bmatrix} \qquad (7)$$

Step 2: Weighting the supermatrix. Under the criteria of the control layer, compare the importance of each element group U_i(i = 1, 2, ..., N) in the network layer to the element group U_j to obtain the weighted matrix A.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1N} \\ \vdots & & \vdots \\ a_{N1} & \cdots & a_{NN} \end{bmatrix} \qquad (8)$$

Multiplying the matrix A with the matrix W in a block-wise manner allows for the weighting of the elements of matrix W. That is, $\underline{W_{ij}} = a_{ij} W_{ij}$. This yields the weighted supermatrix:

$$\bar{W} = (\overline{W_{ij}}) \qquad (9)$$
$$(i = 1, 2, \cdots, N; j = 1, 2, \cdots, N)$$

Step 3: Calculate the stable weighted supermatrix. Apply stability processing to the weighted supermatrix $\underline{\bar{W}}$ according to Formula (10), ultimately yielding the stable weighted supermatrix W^*.

$$W^* = \lim_{k \to \infty} (1/N) \sum_{k=1}^{N} (\bar{W})^k \qquad (10)$$

.

If this limit exists, then the column vectors of W^* are the limit relative ranking vectors, representing the global weights of each evaluation indicator for the evaluation objective.

Where $W^* = (W1^*, W2^*, ..., WN^*)$.

4.2.3 *Phase 3*：Visualization

After determining the weights of the indicators affecting the health of the post-pandemic settlements, the next step was to calculate their scores. In this study, we chose to take 18 neighborhoods in central Wuhan as an example, and after obtaining the relevant data and information, their respective health outcomes were calculated using the mean and standard deviation values. In the next step, ArcGIS will help to visualize the results.

4.3 Long-lasting impact and Influencing factors

4.3.1 General analysis overview

Out of the total of 165 publications, only 16 were published in 2020, while 51 and 57 papers were published in 2021 and 2022, respectively. The remaining 41 articles belong to the year 2023. From the collated results of the Excel sheet mentioned above, four main categories were summarized, physical, environmental, socioeconomic and demographic. Notably, as not all research focused solely on a single dimension, the resulting combinations encompass seven areas of study containing, Physical, Environmental, Socioeconomic, Demographic, Physical & Socioeconomic, Physical & Demographic, and Socioeconomic & Demographic. The largest number of studies examined the impact of the physical environment on health, with 83 articles accounting for 50.3% of the collected literature. Research on socioeconomic aspects has risen rapidly in recent years, with 28 studies accounting for 17% of the literature. This is followed by demographic studies at 11.5%. There were 15 and 11 papers, respectively, studying physical & socioeconomic and physical & demographic impact, constituting 9.1% and 6.7% of the total publications. Only five articles, or 3.0% of the total, examined the environmental dimension of neighborhoods alone(see in Table 4.1).

Table 4.1 Distribution of research dimensions of the included literature

Research dimension	Count	Percentage
Physical	83	50.3%
Environmental	5	3.0%

Socioeconomic	28	17.0%
Demographic	19	11.5%
Physical & Socioeconomic	15	9.1%
Physical & Demographic	11	6.7%
Socioeconomic & Demographic	4	2.4%
Total	165	100

4.3.2 The result of keywords analysis

Keywords co-occurrence analysis reveals the hotspots and internal connections of a particular research topic. The basic principle is to count the number of times a group of words appear in the same set of literature, and measure the affinity between them by the number of co-occurrences (Chen & Song, 2019). The co-occurrence frequency and centrality are two key indicators; the former reflects the hotness of the keywords, and the latter shows the importance of the keywords in the co-occurrence network (Table 4.2). The co-occurrence analysis of keywords shows that ‘built environment’, ‘urban planning’, and ‘physical activity’ are the main research topics. The top five keywords in terms of centrality were ‘accessibility’, ‘mental health’, ‘green infrastructure’, ‘walking’ and ‘benefits’, indicating their central roles in the co-occurrence network.

Table 4.2 Results of co-occurring keywords (occurrence≥8)

No	Keywords	Occurrence	Centrality	No	Keywords	Occurrence	Centrality
1	covid-19	48	0.02	11	human	15	0.1
2	built environment	31	0.05	12	pandemic	15	0.02
3	neighborhood	29	0.1	13	walking	14	0.08
4	urban planning	27	0.07	14	accessibility	10	0.17
5	city	25	0.01	15	impact	10	0.05
6	physical activity	22	0.03	16	space	9	0.01
7	health	22	0.01	17	demography	8	0.04
8	public health	20	0.01	18	residence characteristics	8	0.02
9	community	19	0.05	19	greenspace	8	0.01
10	mental health	16	0.12	20	urban design	8	0.01

Keyword burst detection serves as a metric for identifying rapidly changing hotspots in a short period, reflecting profound shifts in a specific field. Meanwhile, the keyword timeline

provides a clear representation of updates and interactions in the literature. By combining keyword burst detection (Table 4.3) with the timeline graph (Figure 4.2), it becomes evident that in 2020, the prominent keywords were all related to the virus; such as ‘sars’, ‘virus pneumonia’, ‘coronavirus infection’, followed by ‘exercise’, ‘quarantine’ and ‘urbanization’. Notably, there were no keywords directly linked to settlements during this period. Moving to 2021, the emphasis shifted to the the “impact” of the pandemic, with keywords like ‘public transportation’, ‘social capital’, and ‘green space’ appearing and emphasizing the ‘association’ and ‘benefits’ between these factors and health. However, these hotspots were short-lived and rapidly iterated, with only ‘exercise’ of 2020 persisting into 2021. In 2022, a new set of keywords emerged, including ‘environmental planning’, ‘urban design’, ‘life’, ‘quality’, and these trends have persisted to the present.

Figure 4.2 shows the interrelationships between studies over the year, revealing a general trend of declining research interest from 2020 to 2023, with 2021 being the year with the highest emergence of new hotspots. Keywords initiated during this period—such as ‘mental health’, ‘accessibility’, and ‘green infrastructure’—laid the groundwork for subsequent research development. As described in Methodology, bridge nodes serve as crucial points to explain pivotal shifts in research evolution and signify how studies in the field transition between preceding and subsequent concepts. Bridge nodes in 2020 include ‘coronavirus disease 2019’, ‘human’, and ‘humans’, which can be seen as the cause and beginning of settlement research under the impact of the pandemic. In 2021, ‘accessibility’ emerged as a bridge, linking the prior appearance of ‘infrastructure’ with the subsequent words like ‘parks’, ‘social inequality’, and ‘15-minute city’. This implies that within the pandemic context, research on neighborhood areas progressed from a broad focus on infrastructure to a subsequent emphasis on green spaces, delving into uncovering the relationship between accessibility and social inequality, ultimately leading to discussions about new urban models. Following that, ‘mental health’ emerged as a bridge connecting the preceding research keywords ‘depression’ to the subsequent ‘space’, ‘urban design’, and the recent additions of ‘affordability’ and ‘old adults’. This progression indicates the evolution of research from phenomena exploration to build environment analysis and attributing socioeconomic

variables. Another important node in 2021, ‘green infrastructure’, jointly connected ‘accessibility’ and ‘mental health’, demonstrating its intermediary role between the two. The turning point in 2022 appeared with ‘urban health’, linking ‘human’, ‘adult’, ‘female’, ‘ood insecurity’, and subsequently, ‘land use’, ‘stakeholder’, ‘local government’ and ‘politics’. This highlights recent research determination in proposing health-promoting solutions, particularly emphasizing organizational management aspects.

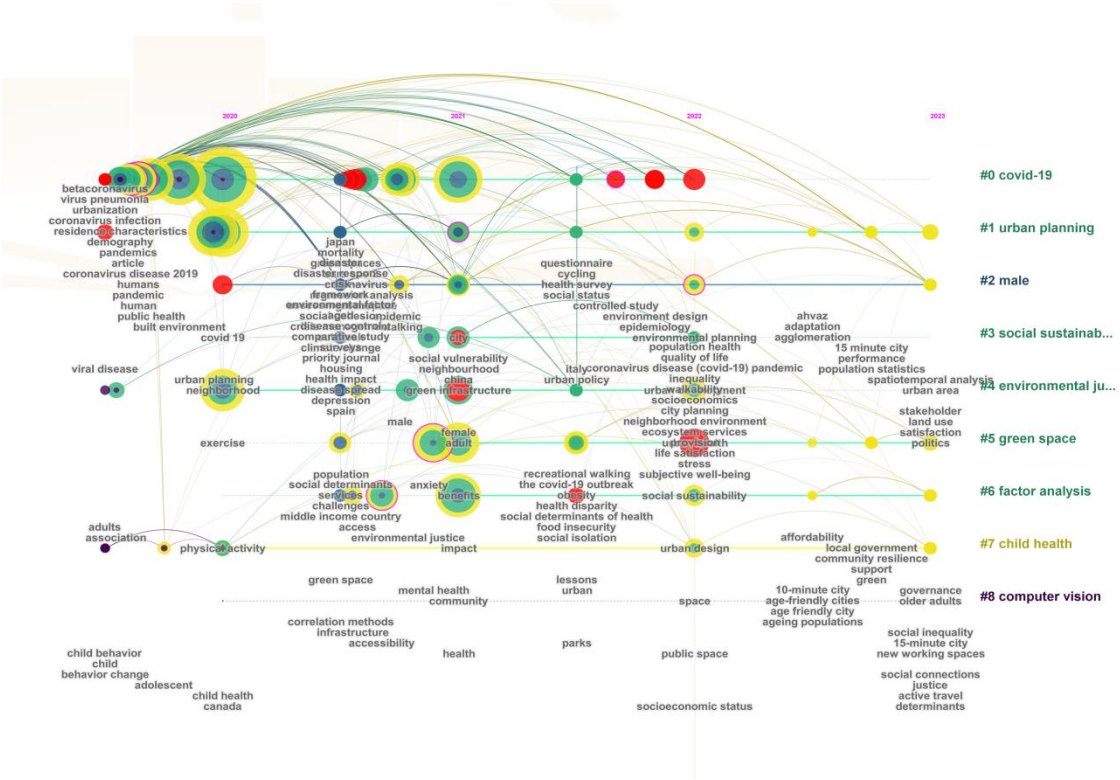


Figure 4.2 Co-occurring keywords timeline from 2020 to 2023 in CiteSpace

Table 4.3 Keywords burst detection from 2020 to 2023

Keywords	Year	Strength	Begin	End	2020 - 2023
sars	2020	1.79	2020	2020	
viral disease	2020	1.79	2020	2020	
exercise	2020	1.22	2020	2021	
quarantine	2020	1.19	2020	2020	
virus pneumonia	2020	1.19	2020	2020	
pneumonia	2020	1.19	2020	2020	
urbanization	2020	1.19	2020	2020	
coronavirus infections	2020	1.19	2020	2020	
betacoronavirus	2020	1.19	2020	2020	
coronavirus infection	2020	1.19	2020	2020	
participation	2020	1.19	2020	2020	
pandemics	2020	1.02	2020	2020	
impact	2021	2.25	2021	2021	
coronavirus	2021	2.02	2021	2021	
sars cov 2	2021	1.61	2021	2021	
public transport	2021	1.21	2021	2021	
social capital	2021	1.21	2021	2021	
green spaces	2021	1.21	2021	2021	
infectious disease	2021	1.21	2021	2021	
associations	2021	1.21	2021	2021	
benefits	2021	1.02	2021	2021	
environmental planning	2022	1.64	2022	2023	
urban design	2022	1.31	2022	2023	
quality	2022	0.98	2022	2023	
controlled study	2022	0.98	2022	2023	
life	2022	0.98	2022	2023	
perception	2022	0.98	2022	2023	
parks	2022	0.98	2022	2023	
space	2022	0.87	2022	2023	

4.3.3 The result of influencing factors analysis

Table 4.4-1 to 4.4-4 show the synthetic evaluation results derived from the Excel sheet that mentioned in the methodology section. The analysis encompasses a total of 40 factors affecting the health of settlements from a post-pandemic perspective. Notably, the physical dimension emerges as the most impactful, encompassing 23 factors. The environmental dimension contains 3 factors, the demographic dimension involves 9 factors, and the socioeconomic dimension includes 5 factors.

4.3.3.1 Physical dimension

A significant number of built environment factors exhibit strong associations with settlement health during and after COVID-19 pandemic. This study categorized them broadly into built environment and resources, as well as mobility and accessibility.

With respect to the built environment and resources, factors like building density, residential greenery, open public spaces, and local services have received the most significant attention. These three factors have been shown to be associated with better physical health, mental health and health equity outcomes, with the exception of the controversial effect of high building density on neighborhood health. Specifically, residential greenery has demonstrated a significant increase in mental resilience of residents during shocks, helping them maintain physical activity levels comparable to those before the pandemic and facilitating social interactions (Ribeiro et al., 2021). Furthermore, factors negatively impacting health outcomes mainly include insufficient living space and over-density of commercial areas, both of which have been demonstrated to be associated with a higher number of COVID-19 cases (Mouratidis, 2022). In addition to this, health-supported and flexible design strategies, outdoor assets, urban farming and community garden (for food), sharing spaces (ie. coworking space), as representatives of significant changes in neighborhoods under the coronavirus have also been shown to be associated with health outcomes. On the contrary, housing layout, gated community, primary medical facilities, and handwashing facilitators have received limited attention concerning their association with health outcomes.

In terms of mobility and accessibility, access to blue and green spaces significantly contributes to improved physical health, mental health, and health equity outcomes (Sun et al., 2023). Walking /cycling facilities, deemed essential for human mobility and crucial for residents' physical activity and public interaction (Palm et al., 2021), gained prominence under the influence of implementing city closure and social distance measures. This aspect has become the most focal point in this area. Other factors such as accessibility to public open space, infrastructures of healthcare, local services, and public transit, have also generated considerable discussion and have all proved relevant to health equity.

4.3.3.2 Environment dimension

Since this study focuses on the neighborhood level, the scale is relatively microscopic. Therefore, the environmental dimension involves only three indicators, including exposure to air pollutants (PM10, NO2, NO), capacity of wastewater surveillance and capacity of solid waste management (SWM). While other studies have explored variables like temperature and humidity, these were not strongly correlated with healthy communities. The research on these three environmental factors relies on cross-sectional research methods, lacking longitudinal studies, which makes the relationship with health equity unclear.

4.3.3.3 Demographic dimension

In the demographic dimension, the study identifies residence characteristics that negatively impact health, including minority racial/ethnic populations, poverty, extended family cohousing, female gender, low educational attainment, older age, and the presence of chronic disease or other pre-existing health problems. Racial/ethnic minorities and poverty are identified as the most significant threatening factors, significantly affecting health equity. Evidence suggests that African, Hispanic, or informal residents lack the same access to healthcare resources and services as others (Wali, B, 2023). Nevertheless, home-based workers are considered beneficiaries in terms of health as they have the option to stay at home or reduce their outings during the pandemic phase (Zenkteler et al., 2022). The ability to work from home is therefore considered a contributing residential factor to health, as mentioned in Section 4.3.3.1 regarding sharing spaces.

4.3.3.4 Socioeconomic dimension

In the socioeconomic dimension, social capital is a distant second in concern. Social capital is a factor associated with adherence to government recommendations, directly influencing the spread of the virus and health outcomes related to influenza. Communities with high social capital have demonstrated greater resilient to pandemic crisis, through mobilization and sharing of resources and knowledge, as well as post-disaster community reconstruction and recovery (Murayama et al., 2021; Liu et al., 2023; Trucu & Rotolo, 2022). Following social capital is social cohesion and social trust, Zetterberg et al (2021) noted that neighborhood relationships become more important when access to and use of public social support services may be reduced. The mutual care and support among residents formed the backbone of community cohesion during the pandemic, positively impacting residents' mental health. Another noteworthy aspect is the study of digital preparedness and solutions, emphasizing the need to respond to possible future outbreaks, including communication innovations such as online healthcare, big data monitoring (Hassankhani et al., 2021). Furthermore, quality property services (Chen et al., 2023) and residential stability (Zhu & Holden, 2023) have also shown to be associated with health outcomes, although the number of studies on these aspects is limited.

Table 4.4-1 Summary of evidence from included studies in physical dimension

	Risk Factors		Health outcomes during or after pandemic		
			Physical health	Mental health	Health equity
Physical dimension	Built environment and Resources	High built-up density	*Inconsistent*	*Inconsistent*	
		Courtyard housing layout		*Positive*	
		Outdoor assets	*Positive*	*Positive*	*Positive*
		Gated community	*Positive*		
		Limited living space per person	*Negative*	*Negative*	
		Health-oriented tactical design strategies	*Positive*		*Positive*
		Land-use mixture	*Inconsistent*		
		High density of commercial land	*Negative medium*		
		Residential greenery	*Positive*	*Positive*	
		Public open space		*Positive*	*Positive*
		Local services		*Positive*	*Positive*

Table 4.4-1 (Continued)

	Risk Factors		Health outcomes during or after pandemic		
			Physical health	Mental health	Health equity
Physical dimension	Built environment and Resources	Urban farming and community garden (for food)	*Positive*	*Positive*	*Positive*
		Primary medical facilities	*Positive*	*Positive*	*Positive*
		Handwashings facilitators	*Positive*		*Positive*
		Sharing spaces (ie. coworking space)	*Positive*	*Positive*	
		Proximity to the city center	*Negative*	*Negative*	
	Mobility and Accessibility	Walking/Cycling facilities		*Positive*	*Positive*
		High frequency of community park/garden use	*Positive*	*Positive*	
		Accessible to public transit	*Inconsistent*		
		Accessible to blue and green space			*Positive*
		Accessible to public open space	*Positive*	*Positive*	*Positive*

Table 4.4-1 (Continued)

Risk Factors		Health outcomes during or after pandemic		
		Physical health	Mental health	Health equity
	Accessible to infrastructures of healthcare	*Positive*	*Positive*	*Positive*
	Accessible to local services	*Positive*	*Positive*	*Positive*

Table 4.4-2 Summary of evidence from included studies in environmental dimension

	Risk Factors	Health outcomes during or after pandemic		
		Physical health	Mental health	Health equity
Environment dimension	Exposure to air pollutants (PM10, NO2, NO)	*Negative*		
	Capacity of wastewater surveillance	*Positive*		
	Capacity of Solid waste management (SWM)	*Positive*		

Table 4.4-3 Summary of evidence from included studies in demographic dimension

	Risk Factors	Health outcomes during or after pandemic		
		Physical health	Mental health	Health equity
Demographic dimension	Population with pre-existing chronic diseases or other health issues	*Negative*		
	Home-based workers	*Positive*		*Negative*
	Minority racial/ethnic populations	*Negative*	*Negative*	*Negative*
	Poverty	*Negative*	*Negative*	*Negative*
	Big household size	*Negative*		
	Female	*Negative*	*Negative*	
	High population density	*Negative*		
	Low education level（Below high school）	*Negative*		
	Aging population (over 65)	*Inconsistent*	*Negative*	*Negative*

Table 4.4-4 Summary of evidence from included studies in socioeconomic dimension

	Risk Factors	Health outcomes during or after pandemic		
		Physical health	Mental health	Health equity
Socioeconomic dimension	Social capital		*Positive*	*Positive*
	High property fee	*Positive*		
	Social cohesion and Social trust	*Positive*	*Positive*	*Positive*
	Residential stability		*Positive*	
	Digital preparedness and solutions	*Positive*	*Positive*	*Positive*

4.4 Evaluative model building based on DEMATEL and ANP

Among the 40 indicators summarized in section 4.3, 35 indicators were regarded as suitable for measuring neighborhood health in the specified context of Wuhan, as the updated data for five indicators were not accessible for further analysis. Thus, these factors affecting the health of neighborhoods in the post-pandemic period were finally selected, including 19 physical, 3 environmental, 8 demographic, and 5 socioeconomic factors.

The steps to determine the set of impact dimensions were:
C= {C1,...,Ci,...,CN} = {Physical, Environmental, Demographic, Socioeconomic factors} , (i = 1, 2,...,N), and determine the affiliation between the impact dimensions and assessment indicators.

C1 = {C1,C12,C13,C14,C15,C16,C17,C18,C19,C110,C111,C112,C113,C114,C115.
C116,C117,C118,C119} = {Building density, size of outdoor facilities, per capita living area , land use mix, density of commercial land, greening rate, size of public open space, size of local public service facilities, size of rooftop/community gardens, size of primary healthcare facilities, and size of community garden, size of primary healthcare facilities, number of public hand-washing facilities, size of shared spaces (e.g. co-working spaces), distance to city center, size of walking/biking facilities, distance to public transportation stops, accessibility to blue and green spaces, accessibility to public open spaces, accessibility to healthcare Infrastructure, accessibility to local services }.

C2 = {C21, C22, C23} = {Air Quality, Sewage Capacity, Solid Waste Capacity}.

C3 ={C31, C32, C33, C34, C35, C36, C37, C38}={Poverty Rate, Population Density, Gender, Educational Attainment Below High School, Aging rate, Home-based workers (%),Living space per capita, and percentage of people with basic/chronic illnesses (%)} .

C4 = {C41, C42, C43, C44, C45} = {Social capital level, property fee, Social cohesion,

residential stability, digital readiness }.

Table 4.5 Evaluation Indicator System

Category	Sub-category	Risk factors
Physical C1	Built environment and Resources	Built-up density C11
		Outdoor assets C12
		Living space per person C13
		Land-use mixture C14
		Density of commercial land C15
		Residential greenery C16
		Scale of public open space C17
		Scale of local services C18
		Scale of urban farming and community garden (for food) C19
		Scale of primary medical facilities C110
		Number of handwashing facilitators C111
		Scale of sharing spaces (i.e. coworking space) C112
	Mobility and Accessibility	Distance to the city center C113
		Amount of walking/cycling facilities C114
		Accessibility to public transit C115
		Accessibility to blue and green space C116
		Accessibility to public open space C117
		Accessibility to infrastructures of healthcare C118
		Accessibility to local services C119
Environmental C2	No subcategory	Exposure to air pollutants (PM10, NO2, NO) C21
		Capacity of wastewater surveillance C22
		Capacity of Solid waste management(SWM) C23
Demographic C3	No subcategory	Percent of Poverty C31
		Population density C32
		Percent of Female C33
		Percent of Low education level（Below high school）C34
		Percent of Aging population (over 65) C35
		Percent of Home-based workers C36
		Household size C37
		Percent of population with pre-existing chronic diseases or other health issues C38

Socioeconomic C4	No subcategory	Social capital (i.e. community engagement and citizen participation) C41
		High property fee C42
		Social cohesion and Social trust C43
		Residential stability C44
		Digital preparedness and solutions C45

4.4.1 Integrated Impact Matrix Calculation and Network Relationship Modeling

Creating a pairwise comparison matrix for each pair of elements is a common method of decision analysis. The ANP method seeks to weight indicators more objectively than the traditional AHP method. So, survey questionnaires and interviews with experts in relevant fields were designed (see in Appendix) to determine the direct influence relationships between indicators by ANP method. Participants were required to make relative importance judgments between each pair of elements, usually using a scale of 1-9, where 1 indicates equal importance and 9 indicates extreme importance. Based on the original data collected by questionnaire survey, the initial impact matrix M_D was constructed between the assessment indicators, as shown in Table 4.6-1 to 4.6-5.

The initial direct impact matrix M_D was standardized according to formula (2), and the comprehensive impact matrix M_T was obtained by formula (3). Through the discussion of experts and combined with the actual situation, the threshold value was set to 0.1. If the value in the impact matrix is less than 0.1, the impact relationship between the indicators is considered to be weak. The modified matrix M_T is obtained, as shown in Table 4.7-1 to 4.7-5.

According to formula (4) and formula (5), the influence degree r, the influenced degree c, the center degree (r+c) and the cause degree (r-c) are calculated. The correlation between the indicators can be shown by the modified comprehensive influence matrix MT and the causal diagram, see in Table 4.8.

Table 4.6-1 Initial Impact M_{D-} C1

	C11	C12	C13	C14	C15	C16	C17	C18	C19	C110	C111	C112
C11	0	0.161	0.107	0.066	0.168	0.051	0.026	0.056	0.075	0.051	0.129	0.11
C12	0.009	0	0.025	0.025	0.042	0.017	0.016	0.02	0.025	0.028	0.08	0.071
C13	0.014	0.061	0	0.049	0.066	0.022	0.035	0.023	0.031	0.015	0.076	0.106
C14	0.023	0.06	0.031	0	0.066	0.023	0.034	0.04	0.031	0.042	0.07	0.089
C15	0.009	0.036	0.023	0.023	0	0.011	0.015	0.025	0.016	0.02	0.051	0.064
C16	0.03	0.089	0.067	0.064	0.134	0	0.047	0.067	0.061	0.064	0.173	0.14
C17	0.058	0.096	0.043	0.045	0.101	0.032	0	0.056	0.03	0.045	0.159	0.138
C18	0.027	0.076	0.066	0.037	0.06	0.022	0.027	0	0.061	0.021	0.127	0.127
C19	0.02	0.061	0.049	0.049	0.096	0.025	0.051	0.025	0	0.037	0.148	0.211
C110	0.03	0.054	0.101	0.036	0.074	0.024	0.034	0.07	0.041	0	0.097	0.134
C111	0.012	0.019	0.02	0.021	0.03	0.009	0.009	0.012	0.01	0.016	0	0.067
C112	0.014	0.021	0.014	0.017	0.023	0.011	0.011	0.012	0.007	0.011	0.022	0

Table 4.6-2 Initial Impact M_{D-} C1

	C113	C115	C116	C117	C118	C119
C113	0	0.035	0.017	0.019	0.025	0.035
C114	0.186	0	0.028	0.024	0.031	0.054
C115	0.14	0	0.018	0.02	0.022	0.054
C116	0.292	0.279	0	0.11	0.046	0.097
C117	0.264	0.243	0.045	0	0.061	0.097
C118	0.194	0.22	0.107	0.081	0	0.189
C119	0.14	0.092	0.051	0.051	0.026	0

Table 4.6-3 Initial Impact M_{D-} C2

	C21	C22	C23
C21	0	0.486	0.514
C22	0.078	0	0.28
C23	0.073	0.135	0

Table 4.6-4 Initial Impact M_{D-} C3

	C31	C32	C33	C34	C35	C36	C37	C38
C31	0	0.035	0.208	0.171	0.092	0.199	0.161	0.064
C32	0.098	0	0.183	0.183	0.097	0.199	0.152	0.088
C33	0.016	0.019	0	0.054	0.039	0.077	0.022	0.019

C34	0.02	0.019	0.064	0	0.022	0.077	0.024	0.016
C35	0.037	0.035	0.088	0.154	0	0.205	0.15	0.097
C36	0.017	0.017	0.044	0.044	0.017	0	0.021	0.014
C37	0.021	0.022	0.157	0.144	0.023	0.161	0	0.021
C38	0.053	0.039	0.175	0.22	0.035	0.242	0.161	0

Table 4.6-5 Initial Impact M_{D-} C4

	C41	C42	C43	C44	C45
C41	0	0.392	0.148	0.118	0.341
C42	0.013	0	0.091	0.037	0.038
C43	0.035	0.058	0	0.124	0.189
C44	0.044	0.142	0.042	0	0.12
C45	0.015	0.138	0.028	0.044	0

Table 4.7-1 Modified Integrated Impact M_{T-}C1

	C001	C002	C003	C004	C005	C006	C007	C008	C009	C010	C011	C012
C11	0.03	0.236	0.164	0.119	0.257	0.08	0.065	0.102	0.117	0.093	0.255	0.262
C12	0.021	0.029	0.047	0.044	0.075	0.027	0.029	0.036	0.04	0.043	0.122	0.124
C13	0.03	0.099	0.03	0.073	0.111	0.037	0.053	0.046	0.051	0.037	0.137	0.176
C14	0.039	0.103	0.065	0.029	0.116	0.04	0.053	0.065	0.054	0.064	0.138	0.168
C15	0.018	0.059	0.041	0.038	0.029	0.02	0.026	0.039	0.029	0.033	0.087	0.108
C16	0.058	0.162	0.123	0.112	0.217	0.029	0.08	0.109	0.1	0.101	0.284	0.277
C17	0.081	0.159	0.093	0.087	0.175	0.057	0.03	0.092	0.065	0.078	0.253	0.252
C18	0.046	0.126	0.103	0.071	0.12	0.042	0.051	0.03	0.086	0.049	0.203	0.221
C19	0.042	0.116	0.089	0.085	0.158	0.046	0.075	0.058	0.03	0.066	0.228	0.305
C110	0.051	0.112	0.141	0.074	0.14	0.045	0.06	0.1	0.072	0.03	0.184	0.237
C111	0.019	0.038	0.034	0.033	0.051	0.016	0.018	0.023	0.02	0.025	0.029	0.099
C112	0.019	0.037	0.026	0.027	0.042	0.017	0.018	0.021	0.016	0.02	0.047	0.029

Table 4.7-2 Modified Integrated Impact M_{T-} C1

	C013	C014	C015	C016	C017	C018	C019
C113	0.049	0.05	0.065	0.028	0.031	0.034	0.055
C114	0.246	0.039	0.05	0.045	0.044	0.047	0.085
C115	0.187	0.03	0.039	0.032	0.036	0.035	0.077
C116	0.493	0.26	0.385	0.049	0.156	0.092	0.186
C117	0.443	0.271	0.332	0.087	0.048	0.1	0.177
C118	0.418	0.257	0.346	0.153	0.137	0.049	0.273
C119	0.245	0.139	0.155	0.073	0.076	0.049	0.048

Table 4.7-3 Modified Integrated Impact M_{T}-C2

	C21	C22	C23
C21	0.104	0.637	0.746
C22	0.113	0.104	0.367
C23	0.096	0.196	0.104

Table 4.7-4 Modified Integrated Impact M_{T}-C3

	C31	C32	C33	C34	C35	C36	C37	C38
C31	0.04	0.068	0.332	0.303	0.137	0.362	0.238	0.107
C32	0.139	0.04	0.334	0.338	0.151	0.391	0.249	0.138
C33	0.029	0.029	0.041	0.094	0.052	0.126	0.05	0.034
C34	0.031	0.028	0.099	0.04	0.036	0.122	0.049	0.029
C35	0.071	0.064	0.207	0.27	0.042	0.343	0.217	0.129
C36	0.026	0.024	0.074	0.074	0.028	0.04	0.041	0.025
C37	0.042	0.04	0.215	0.204	0.05	0.237	0.042	0.044
C38	0.088	0.07	0.294	0.334	0.082	0.386	0.227	0.041

Table 4.7-5 Modified Integrated Impact M_{T}- C4

	C41	C42	C43	C44	C45
C41	0.029	0.503	0.218	0.186	0.433
C42	0.021	0.032	0.101	0.056	0.072
C43	0.048	0.132	0.032	0.148	0.234
C44	0.053	0.194	0.073	0.03	0.163
C45	0.022	0.162	0.049	0.059	0.03

Table 4.8 Influence, Influenced, Centrality and Causality of Indicators

	Impact D-value	Influenced C-value	Centrality D+C value	Causality D-C value (R)
C11	1.78	0.454	2.234	1.327
C12	0.636	1.276	1.912	-0.64
C13	0.879	0.955	1.834	-0.076
C14	0.933	0.792	1.725	0.141
C15	0.527	1.492	2.019	-0.964
C16	1.652	0.456	2.108	1.196
C17	1.42	0.558	1.978	0.863
C18	1.147	0.721	1.868	0.427

C19	1.299	0.681	1.979	0.618
C110	1.246	0.636	1.882	0.61
C111	0.406	1.968	2.374	-1.562
C112	0.321	2.259	2.58	-1.938
C113	0.312	2.082	2.394	-1.77
C114	0.555	1.046	1.6	-0.491
C115	0.435	1.372	1.807	-0.937
C116	1.622	0.467	2.089	1.155
C117	1.459	0.527	1.987	0.932
C118	1.633	0.405	2.038	1.228
C119	0.785	0.901	1.686	-0.116
C21	1.488	0.313	1.801	1.174
C22	0.584	0.937	1.521	-0.353
C23	0.396	1.218	1.614	-0.822
C31	1.587	0.466	2.053	1.121
C32	1.781	0.363	2.144	1.419
C33	0.454	1.596	2.05	-1.141
C34	0.434	1.658	2.092	-1.224
C35	1.341	0.578	1.919	0.764
C36	0.333	2.007	2.34	-1.674
C37	0.872	1.112	1.985	-0.24
C38	1.521	0.546	2.067	0.976
C41	1.37	0.174	1.543	1.196
C42	0.281	1.023	1.305	-0.742
C43	0.594	0.473	1.067	0.121
C44	0.513	0.479	0.993	0.034
C45	0.324	0.932	1.256	-0.609

4.4.2 Calculation of weights of indicators for each level of assessment

According to the mutual influence relationship between indicators and the network relationship model of influence level obtained by DEMATEL method, combined with the identified assessment indicator system and assessment indicator set, the ANP network hierarchy model for the assessment of post-pandemic neighborhood is constructed.

The ANP network hierarchy algorithm was used and the Super Decision v2.6.0 software was applied to calculate the weighted supermatrix, which was stabilized to finally obtain the limit relative ranking vector W*. In this extreme relative ranking vector W*, each element represents the weight of the corresponding criterion, and these weights reflect the relative importance of each factor to the target. Each element in the extreme relative ranking vector

W* represents the weight of the corresponding criterion. In this study, there are four criteria, so there are four weight values in W*. The sum of these weight values is 1 because they are relative weights, which are used to indicate the relative importance of each factor to the objective. A larger weight value means that the corresponding criterion has a greater influence on the goal. The values of the extreme relative ranking vector W* allow for decision making. Resource allocation is optimized, strategies are formulated, and prioritization is done based on these weight values. The extreme relative ranking vector W* can also be used to perform sensitivity analysis and impact assessment of decision options. By adjusting the weight values of the factors in W*, the degree of impact of different decision scenarios on the final goal can be assessed and the best scenario can be selected.

After calculating the weighted supermatrix, the weights of the indicators are calculated through the following steps. In the ANP method, the calculation of weights involves a series of matrix operations and eigenvalues as follows:

- The weighted supermatrix was calculated using the ANP method. The weighted supermatrix reflects the two-by-two comparison between different criteria and the relative weight relationship between them, and the matrix is usually denoted by A.
- Stability processing is applied to the weighted supermatrix to ensure the stability of the results. Stability processing eliminates errors and biases in the matrix computation in order to obtain reliable results.
- Calculate the eigenvectors. An eigenvector is a non-zero vector of a matrix A whose direction does not change under the action of the matrix A and only its length changes. The eigenvector is denoted by V.
- Calculate the eigenvalues. The eigenvalue is the value corresponding to the eigenvector, which is obtained by solving the eigenequation, and the eigenvalue is usually denoted by λ.
- Normalize the eigenvalues according to a certain rule to ensure that their sum is 1. The normalized eigenvalues obtained in this way are the weights of each indicator.

W*=（W1*，W2*，…Wn*）=（0.0404，0.0367，0.0398，0.0328，0.0280，0.0311，0.0175，0.0420，0.0036，0.0123，0.0106，0.0081，0.0315，0.0267，0.0345，0.0471，

0.0104, 0.0208, 0.0249, 0.0412, 0.0096, 0.0312, 0.0440, 0.0415, 0.0405, 0.0332, 0.0140, 0.0376, 0.0321, 0.0362, 0.0151, 0.0337, 0.0245, 0.0356, 0.0316）

Combining the above, the weights of the indicators for health assessment of the post-pandemic neighborhoods can be obtained as in Table 4.9.

Table 4.9 Impact dimensions and weighting of indicators

Levels of influence and weighting	Risk factors	Global weight	local weight
Physical 0.4984	Built-up density	0.0404	0.091
	Outdoor assets	0.0367	0.078
	Living space per person	0.0398	0.075
	Land-use mixture	0.0328	0.07
	Density of commercial land	0.0280	0.082
	Residential greenery	0.0311	0.086
	Scale of public open space	0.0175	0.081
	Scale of local services	0.0420	0.076
	Scale of urban farming and community garden (for food)	0.0036	0.081
	Scale of primary medical facilities	0.0123	0.077
	Number of handwashing facilitators	0.0106	0.097
	Scale of sharing spaces (i.e. coworking space)	0.0081	0.105
	Distance to the city center	0.0315	0.176
	Amount of walking/cycling facilities	0.0267	0.118
	Accessibility to public transit	0.0345	0.133
	Accessibility to blue and green space	0.0471	0.154
	Accessibility to public open space	0.0104	0.146
	Accessibility to infrastructures of healthcare	0.0208	0.15
	Accessibility to local services	0.0249	0.124
Environmental 0.0820	Exposure to air pollutants (PM10, NO2, NO)	0.0412	0.365
	Capacity of wastewater surveillance	0.0096	0.308
	Capacity of Solid waste management(SWM)	0.0312	0.327
Demographic 0.2791	Percent of Poverty	0.0440	0.123
	Population density	0.0415	0.129
	Percent of Female	0.0405	0.123
	Percent of Low education level （Below high school）	0.0332	0.126

	Percent of Aging population (over 65)	0.0140	0.115
	Percent of Home-based workers	0.0376	0.141
	Household size	0.0321	0.119
	Percent of population with pre-existing chronic diseases or other health issues	0.0362	0.124
Socioeconomic 0.1405	Social capital (i.e. community engagement and citizen participation)	0.0151	0.25
	High property fee	0.0337	0.212
	Social cohesion and Social trust	0.0245	0.173
	Residential stability	0.0356	0.161
	Digital preparedness and solutions	0.0316	0.204

From the table above, it was found that the impact dimensions and weights are categorized into physical, environmental, demographic and socioeconomic factors. Each impact level contains a number of specific indicators, which reflect their importance in the overall evaluation and their weights in specific factors through global weights and local weights.

It can be seen that air quality (PM2.5) among the environmental factors has a high global weight of 0.0412 and a local weight of 0.365, which indicates that air quality has a greater impact on the overall evaluation and occupies an important position among the environmental factors. Although the global weights of indicators such as building density, size of outdoor facilities, and per capita living area in the physical factors are small, their importance in the physical factors can be seen through the local weights. For example, the global weight of building density is 0.0404, while the local weight is 0.091, indicating that building density still has a certain influence in the physical factors although its weight is not high in the overall evaluation. Indicators such as poverty ratio, population density, social capital level, and property fees in demographic and socioeconomic factors also have different degrees of global and local weights, reflecting their importance in the overall evaluation as well as their weights in different factors. The data on weights can help to better understand the impact of each factor and the specific indicators under it on the overall evaluation, and contribute to more scientific decision-making and analysis in practical applications.

4.5 Visualization of the framework: The case of Wuhan

This section conducted an empirical case study based on the evaluation index system established in the previous section. Shouyi of Wuchang District, Wuhan is taken as the research object, and through summarizing and sorting out data in four dimensions: physical, environmental, demographic and socioeconomic, it concludes with a detailed analysis of the health of its neighborhoods.

4.5.1 Overview of research subjects

Figure 4.3 Urban district of Wuhan, China

Figure 4.4 Scope of Research Subject

Wuhan is the capital city of Hubei Province in China. The city has jurisdiction over 13 districts with a total area of 8,569.15 square kilometers. By the end of 2022, the permanent population was 13,739,000. The Shouyi area selected in this study is adjacent to Yangzi River in the north, southeast of Wuchang district. It is east to Changchun Guan and South Zhongnan Road Street connected to the south to the uprising door of the Shouyi Road and Ziyang Street adjacent to the west adjacent to the Ziyang Lake, the north of the southern foothills of Serpentine Mountain and the Grain Road Street across the mountain, with a total area of 2.7

square kilometres. Shouyi area jurisdiction of eight neighborhoods: Wunan Village , Dandongmen, Qianjiajie, Changhu, South Central, 701, 719, and Jiangling.

Since the approval of Wuhan's current urban master plan, the current focus has been on settlement renewal. In the new socioeconomic situation, in accordance with the principles of the newly revised settlement planning for 2019, the construction of a "5-minute neighborhood" has been initiated to address grass-roots livelihood issues in an integrated manner. This study examines the size and scale of neighborhoods, following this new regulation. The basic unit typically serves a population of 5,000-12,000 people and has a walkable distance of about 300-400 meters, or about a 5-minute walk from home.

4.5.2 Neighborhood Evaluation Indicator Values Acquisition and Quantitative Scoring

Next, based on the evaluation system constructed above, data were obtained for the indicators of four dimensions, including physical, environment, demographic and socioeconomic. There are main three channels to get access to the required data: ArcGIS, Field research and mapping, and Questionnaire (Figure 4.5). Due to differences in dimensions, large variations in mean values, and the lack of relevant standards for some indicators, it was not possible to assign specific quantified scores to each indicator. Therefore, using the natural breaks method in GIS software, each group of indicators were classified into five categories from high to low. For positive indicators, values of 1, 2, 3, 4, and 5 were assigned sequentially, while for negative indicators, the values were assigned in reverse.

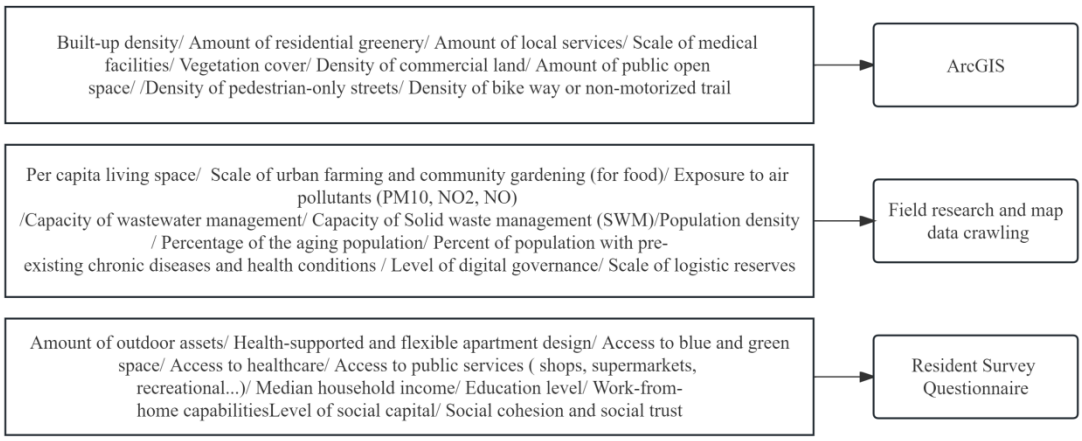


Figure 4.5 Framework of data sources

---Physical dimension

In terms of the physical environment, it includes two aspects: built environment and resources AND mobility and accessibility. Specific sources and modalities of data acquisition are shown in tables 4.10 and 4.11. Among them, the indicators of the built environment include building density, population density, scale of outdoor facilities, congestion mix, green space ratio, etc., which have been processed by the natural break method.

For example, building density is an indicator of residential congestion. The higher the building density, the denser the buildings in the area, the less open space, which is not conducive to outdoor activities for residents, so it is a negative indicator. This study statistically analyzed the building area of Shouyi area through GIS and classified it into 5 categories using the natural break method, which are 4.1%-8.3% (good, assigned a score of 5 points), 8.4%-15.5% (relatively good, assigned a score of 4 points), 15.6%-18.9% (average, assigned a score of 3 points), 19%-21.3% (poor, assigned a score of 2 points), and 21.4%-25.4% (very poor, assigned a score of 1 point). In the same way, the majority of studies have shown that the higher the population density, the more unfavorable it is for the health of the population in the neighborhood, so this study regarded population density as a negative indicator. After classification by the natural break method, the scores were assigned successively as follows: 661.7-741.1 people/km^2 (good, assigned a score of 5 points), 741.2-1593.1 people/km^2 (relatively good, assigned a score of 4 points), 1593.2-2095.1 people/km^2 (average, assigned a score of 3 points), 2095.2-2605.1 people/km^2 (poor, assigned a score of 2 points), 2605.2-3250.8 people/km^2 (very poor, assigned a score of 1 point). Green space ratio, according to GIS natural break method, assigned scores successively as 89%-100% (good, assigned a score of 5 points), 70%-88% (relatively good, assigned a score of 4 points), 49%-69% (average, assigned a score of 3 points), 7%-48% (poor, assigned a score of 2 points), 0-6% (very poor, assigned a score of 1 point), etc.

The scoring results are as follows (Figure 4.6).

Table 4.10 Healthy Environment - built environment and resources indicator measurement

Indicators	Sources
Built-up density	ArcGIS
Outdoor assets	Field research and mapping
Living space per person	ArcGIS
Land-use mixture	ArcGIS
Density of commercial land	ArcGIS
Residential greenery	ArcGIS
Scale of public open space	ArcGIS
Scale of local services	Field research and mapping
Scale of urban farming and community garden (for food)	Field research and mapping
Scale of primary medical facilities	Field research and mapping
Number of hand-washing facilitators	Field research and mapping
Scale of sharing spaces (i.e. co-working space)	Field research and mapping

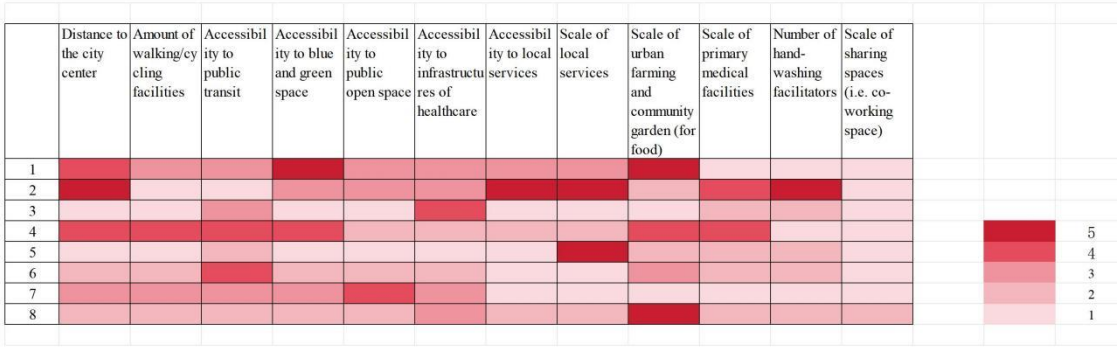


Figure 4.6 Quantitative scoring results for built environment and resources

Likewise, The total length of pedestrian and bicycle lanes is obtained through OpenStreetMap (OSM) road network data. Some of the road network data do not match reality and are corrected through on-site surveys. Finally, the following levels are established using the natural break method: pedestrian lane density 5-6.79km/km^2 (good, assigned a score of 5 points), 4.08-4.99km/km^2 (relatively good, assigned a score of 4 points), 2.39-4.07km/km^2 (average, assigned a score of 3 points), 1.76-2.38km/km^2 (poor, assigned a score of 3 points), 1.02-1.75km/km^2 (very poor, assigned a score of 1 point); as pedestrian accessibility involves residents' environmental and psychological behavioral preferences, it is assessed through questionnaire scoring. The final results for mobility and accessibility is shown in Figure 4.7.

Table 4.11 Healthy Environment - mobility and accessibility indicator measurement

Indicators	Sources
Distance to the city center	ArcGIS
Amount of walking/cycling facilities	Field research and mapping
Accessibility to public transit	Questionnaire
Accessibility to blue and green space	Questionnaire
Accessibility to public open space	Questionnaire
Accessibility to infrastructures of healthcare	Questionnaire
Accessibility to local services	Questionnaire

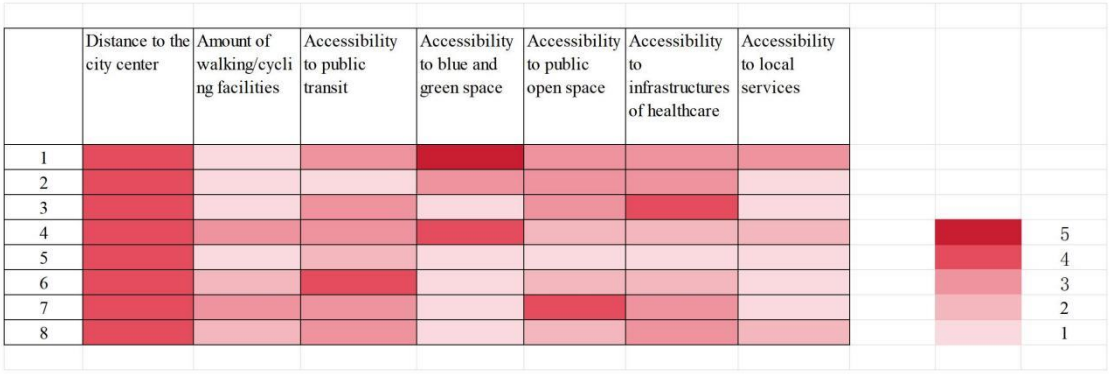


Figure 4.7 Quantitative scoring results for mobility and accessibility

---Environmental dimension

In terms of environmental dimensions, the performance of air quality in the eight residential areas is generally consistent due to their layout in the same area. The difference lies in the capacity for solid waste and sewage treatment, which we obtained through actual visits and surveys (Table 4.12). The final scoring results can be found in Figure 4.8.

Table 4.12 Healthy Environment - environmental indicator measurement

Indicators	Sources
Exposure to air pollutants (PM10, NO2, NO)	Field research and mapping
Capacity of wastewater surveillance	Field research and mapping
Capacity of Solid waste management(SWM)	Field research and mapping

	Exposure to air pollutants (PM10, NO2, NO)	Capacity of wastewater surveillance	Capacity of solid waste management (SWM)		
1					
2					
3					
4					5
5					4
6					3
7					2
8					1

Figure 4.8 Quantitative scoring results for environment

---Demographic dimension

In terms of demographic dimensions, the relevant data of the study subjects are all collected through on-site surveys and questionnaires, as shown in Table 4.13. Based on the overall situation, we still use the natural break method to score the performance of each factor. For example, the proportion of elderly people aged 65 and above is classified as follows: 3.7%-6.1% (good, assigned a score of 5 points), 6.11%-14.9% (relatively good, assigned a score of 4 points), 14.91%-19.1% (average, assigned a score of 3 points), 19.11%-21.8% (poor, assigned a score of 2 points), 21.81%-27.1% (very poor, assigned a score of 1 point). Similarly, for the proportion of population with lower education levels (below high school), the classification based on the natural break method is as follows: 5.6%-8.2% (good, assigned a score of 5 points), 8.2%-13.4% (relatively good, assigned a score of 4 points), 13.4%-16.1% (average, assigned a score of 3 points), 16.1%-23.9% (poor, assigned a score of 2 points), 23.9%-27.5% (very poor, assigned a score of 1 point). The proportion of population with chronic diseases is classified as follows according to the natural break method: 2.7%-4.1% (good, assigned a score of 5 points), 4.1%-7.9% (relatively good, assigned a score of 4 points), 7.9%-10.4% (average, assigned a score of 3 points), 10.4%-12.3% (poor, assigned a score of 2 points), 12.3%-15.9% (very poor, assigned a score of 1 point). The final scoring results can be found in Figure 4.9.

Table 4.13 Healthy Environment - demographic indicator measurement

Indicators	Sources
Percent of Poverty	Field research and mapping
Population density	Field research and mapping
Percent of Female	Field research and mapping
Percent of Low education level（Below high school）	Questionnaire
Percent of Aging population (over 65)	Field research and mapping
Percent of Home-based workers	Questionnaire
Household size	Questionnaire
Percent of population with pre-existing chronic diseases or other health issues	Field research and mapping

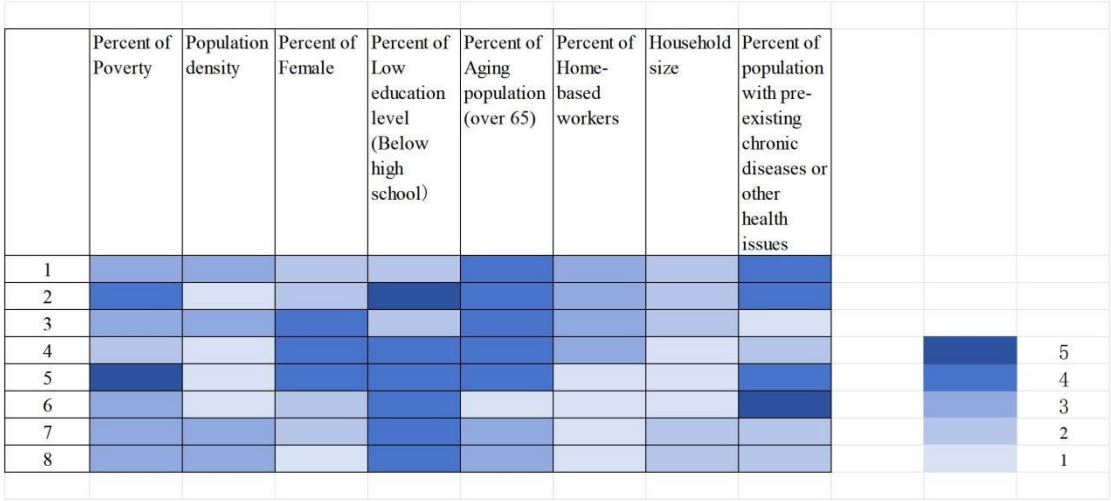


Figure 4.9 Quantitative scoring results for demography

---Socioeconomic dimension

With regard to the socioeconomic dimension, apart from the item of property fees, all other relevant data were collected through questionnaires, as shown in Table 4.14. There is significant variation in the scores for social capital among the eight residential areas, and the data preparation level for these aspects appears to be in urgent need of improvement based on the survey data. The final scoring results can be found in Figure 4.10.

Table 4.14 Healthy Environment - socioeconomic indicator measurement

Indicators	Sources
Social capital (i.e. community engagement and citizen participation)	Questionnaire
High property fee	Field research and mapping
Social cohesion and Social trust	Questionnaire
Residential stability	Questionnaire
Digital preparedness and solutions	Questionnaire

Figure 4.10 Quantitative scoring results for socioeconomic

4.5.3 Evaluation results and analysis

According to the way of assigning points to each indicator combined with the weights determined in Table 4.9, the target neighborhoods were finally evaluated. After statistical analysis, the scoring results of the eight neighborhoods were classified into the following four categories: healthy neighborhood (3.620-4.222), relatively healthy neighborhoods (3.029-3.619), relatively unhealthy neighborhoods (2.250-3.028), and unhealthy neighborhoods (1.912-2.249). See details in Figure.4.11.

It is further compared of the neighborhoods with higher scores to those with lower scores and found that they share similarities in terms of building density and layout. However, the main

reasons for the health disparities lie in the quality, scale of public spaces and facilities, and level of social capital.

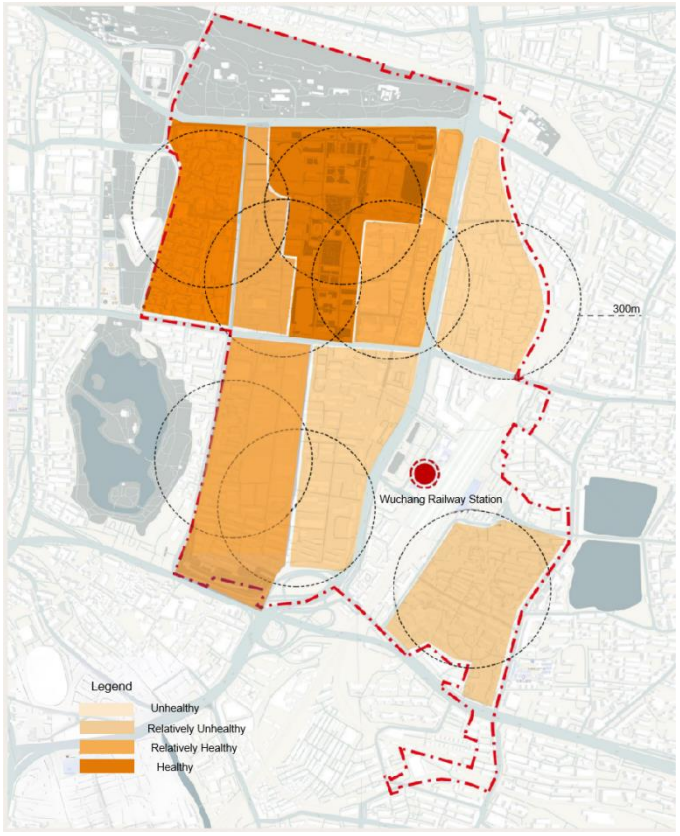


Figure 4.11 Results of the health rating in targeted districts

4.5.3 Analysis of evaluation results and optimization of strategies

Further analysis was conducted on the health levels of 8 residential areas, selecting the well-rated Qianjiajie community (with a score of 3.964) and the relatively poorer-rated 719 community (with a score of 2.236) for comparison. The reason for choosing these two neighborhoods is that, firstly, they are similar in size; secondly, both areas are residential in nature, with the primary land use being residential; finally, the construction time of the two neighborhoods is relatively close, with Qianjiajie community completed in 2008 as a relocated housing community, and the 719 community established in 2004.

The differences between them are primarily reflected in the following aspects:

In terms of built environment evaluation, the weights determined through the Analytic Hierarchy Process were 0.4984, with scores of 1.972 (Qianjiajie) and 0.956 (719) for these two communities in this dimension, which includes environmental facilities and accessibility criteria layers. In terms of environmental facilities, Qianjiajie has significant advantages in building density and green coverage. It can be seen that the north-south pedestrian pathways divide the residential area into 4 parts, connecting various sizes of green spaces, not only providing a good walking environment for the residents but also increasing the green coverage of the neighborhood (see Figure 4.12).

Figure 4.12 Roads of the 719 (Left) and Qianjiajie neighborhood (Right) .

In terms of accessibility, a clear advantage can be observed in Qianjiajie, as shown in the on-site photos from the survey (see Figure 4.12). Although the two plots are adjacent, the 719 community has set up access control in the north-south direction, and there is no continuous road like in Qianjiajie in the east-west direction, resulting in weaker street connectivity and lower road network density indicators. Qianjiajie does not use access control in the north-south direction but instead creates a good walking environment through paving and planting trees, reducing the interference of motor vehicles and providing a good environment for its residents. On the other hand, rational land use can effectively improve the level of public service facilities within the plot. Through the experience of this epidemic, it can be clearly observed that open spaces and flexible land use in land utilization provide important assistance in responding to emergencies. In both Qianjiajie and 719 plots, although they are both residential land uses, Qianjiajie has many commercial spaces around it (see Figure 4.13), providing vitality for community activities, and to a greater extent, facilitating residents' shopping, health care, entertainment, and leisure needs.

Figure 4.13 Ground floor commercial space and public open space in Qianjiajie neighborhood

In terms of environmental assessment, the weight determined through the Analytic Hierarchy Process is 0.0820, and the scores for these two neighborhoods in this dimension are relatively close, at 0.282 (Qianjiajie) and 0.229 (719) respectively. This dimension includes three indicators: air quality, wastewater treatment capacity, and garbage disposal capacity. Based on the research findings, there is generally no significant difference in air quality between the adjacent neighborhoods. Due to Qianjiajie's higher green coverage, its air quality score is slightly higher than that of the 719 community. However, Qianjiajie community has a significant advantage in garbage disposal due to its classified waste treatment and efficient garbage transportation system.

In terms of population assessment, the weight determined through the Analytic Hierarchy Process is 0.2791, and the scores for these two neighborhoods in this dimension are 0.919 (Qianjiajie) and 0.673 (719) respectively. As the Shouyi area is located in the city center with a relatively high population density and a higher proportion of elderly population, the prevalence of chronic diseases and basic illnesses is naturally not low. Therefore, both neighborhoods have relatively low scores in terms of population assessment. This situation reminds urban planners to pay special attention to the preparation work for aging communities during epidemics.

In terms of socio-economic assessment, the weight determined through the Analytic Hierarchy Process is 0.1405, and the scores for these two neighborhoods in this dimension are 0.791 (Qianjiajie) and 0.378 (719) respectively. This dimension includes four indicators:

social capital, community cohesion, residential stability, and digital management level. Both neighborhoods score high in residential stability, with the main difference in final scores lying in social capital and digital management level. Qianjiajie community has always emphasized the cultivation of community spirit, and its open and transparent community information along with regular community activities have instilled a strong sense of belonging and pride among residents. Additionally, after the COVID-19 pandemic, Qianjiajie community has also started to focus on the application of smart technologies in community management, striving to form a new management form based on informatization and intelligent social management and services. Addressing the higher proportion of elderly residents, IoT-related devices have been installed in some areas of the community, allowing elderly residents who choose to age at home to be remotely monitored and cared for through sensors.

Based on the comparison of the overall health assessment scores of the two neighborhoods and their specific differences in physical, environmental, population, and socio-economic aspects, this study proposes the following preliminary transformation ideas for post-pandemic neighborhoods.

Post-pandemic neighborhood environmental construction has made increasing road network density and reducing block scale an indispensable focus. Taking the Shouyi area as an example, measurements have revealed that the length of most residential-dominated communities ranges from 300 to 400 meters, with many communities primarily consisting of single land use and lacking accessible roads. Large-scale communities often face problems such as high population density and inadequate supporting facilities in the face of sudden epidemics. The pandemic has prompted people to reconsider whether high-density living environments are suitable. However, urbanization involves population concentration, and discussing facility configuration without considering density is unrealistic. Public service facilities require a certain population base to operate effectively. Therefore, based on the current situation of the neighborhoods, research on residents' living conditions should be conducted to configure facilities that match the development and needs of the community. Unused land should be reutilized, and parcels that do not meet residents' needs should be

reconfigured and adjusted, integrating surrounding businesses to redesign the flow to enhance the neighborhood's quality of life (see Figure 4.14).

In post-pandemic public service facility construction, not only should the capacity of public service facilities during emergencies be considered, but also residents' daily health-related needs, providing spaces for physical activities. Therefore, in addition to considering the complex service functions, the versatility of service facilities should also be considered, allowing public service facilities to be set up flexibly, turning existing spaces into flexible spaces during emergencies for emergency function changes. One notable impact of the pandemic is on delivery services, with restrictions due to resident isolation, community control, and road closures, limiting end-point delivery services. With the rapid development of e-commerce today, new requirements and challenges are posed to logistics facilities, and some public service facilities can switch functions in emergencies. Additionally, meeting residents' needs for social interaction and physical activities optimizes their lifestyle. For instance, a combination of online and offline modes in commercial facilities will become a new direction for business development in the post-pandemic era. Some commercial facilities within the neighborhood can transform into logistics hubs during emergencies to ensure residents' daily food supply.

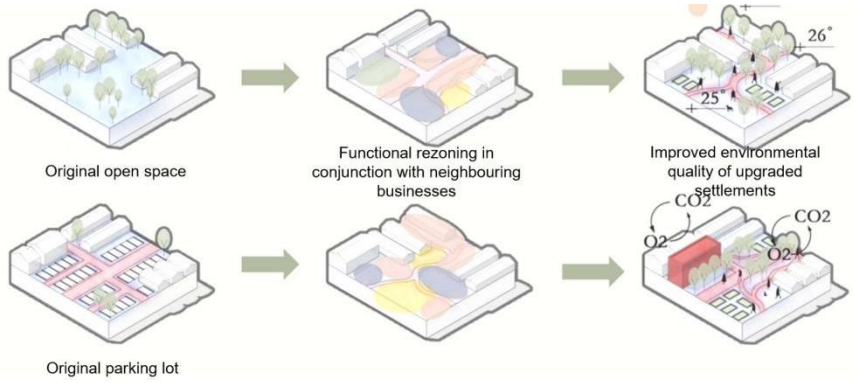


Figure 4.14 Schematic representation of land resource reallocation

Green spaces have been widely proven to promote residents' health, and the recent pandemic has highlighted the importance of constructing parks and green areas. In the existing urban

system, mountains, water bodies, and parks serve as effective isolation methods. Additionally, parks and green spaces act as excellent buffers, providing a good "pandemic-to-normal" transition during public health emergencies. After the outbreak, people have tried to avoid large gatherings in public places as much as possible. Walking is the most common leisure activity and a way to promote residents' health. Linear activity spaces can prevent extensive contact with others when people go out, reducing the risk of infection from crowded areas. During non-pandemic times, greenways also serve as necessary routes for residents' daily travel. Therefore, in neighborhood-scale design, a green network can be constructed, replacing hard pavement with soft green landscapes. In designing green paths, pedestrian walkways should be widened and combined with healthy green paths, with widths ranging from 1.2 to 1.5 meters. Additionally, to enhance residents' spatial experience during travel, flower beds and various landscape elements can be added alongside green paths, or solid walls can be replaced with flower walls to soften boundaries further.

Except for the Zhongnan community, the Shouyi area has relatively few green landscapes and incomplete greenway construction. However, the area has good ecological bases, with the Purple Sun Lake to the west and She Mountain Park to the north. In future development, it is advisable to fully utilize these existing resources and connect them, constructing a greenway network covering the entire Shouyi area to provide residents with a pleasant walking environment (see Figure 4.15).

Figure 4.15 Building a green network of settlements based on the 719 Community

In terms of population, research on community-based elderly care models should be conducted to address the increasingly prominent aging population issue in society. Specifically, this involves creating elderly care stations within community spaces, utilizing IoT (Internet of Things) technology to enhance remote monitoring of the health status of elderly residents. Furthermore, attention should be paid to designing public spaces that cater to the diverse needs of the elderly population for physical exercise, entertainment, social interaction, and more.

Regarding socio-economic aspects, post-pandemic communities in the future will not solely be driven by technology but will also serve as places for repairing and creating new social relationships. Communities should not merely amplify the atomization of contemporary society but should act as catalysts for forming new social groups in a fluid society. From both short-term and long-term perspectives, in areas where the epidemic is relatively under control, urban management should grant communities more authority. Focusing on community spirit cultivation, establishing health information stations centered around communities, and ensuring their long-term maintenance and updates as essential infrastructure will effectively connect communities with individuals, other communities, businesses, and governments, further enhancing community cohesion.

Additionally, emphasis should be placed on the development of smart communities, vertically integrating a comprehensive management platform for smart communities that links government, streets, and communities (see Figure 4.16). This platform should be horizontally connected with multiple systems such as elderly care and health, integrating diverse entities like streets, communities, residents, property management, and businesses. Establishing a community database system based on resident and building conditions, strengthening regional information data resource integration, and promoting community health development are essential. Combined with the renovation of old residential areas, creating a smart property management platform to enhance scientific, precise, intelligent, and convenient neighborhood management is the primary development trend for post-pandemic communities.

Figure 4.16 Building Smart Applications in the neighborhood

4.6 Conclusion

This chapter focuses on post-pandemic residential areas as the research subject. Firstly, it analyzes the main changes in residential area planning during the post-pandemic period, the long-term factors affecting health, and establishes a Post-pandemic Neighborhood Health Evaluation System based on the background of Wuhan. Finally, using the Shouyi area in Wuchang district as an example, empirical analysis is conducted, which holds valuable reference significance for other areas undergoing urbanization processes.

In the specific evaluation process of healthy residential areas, based on the established evaluation indicator system, explanations are provided for the data acquisition methods and scoring methods for each indicator. An overall evaluation of the physical, environmental, demographic, and socioeconomic dimensions of the Shouyi area is done. Among the eight neighborhoods, 2 neighborhoods have good health conditions, 3 neighborhoods have relatively good health conditions, 2 neighborhoods have relatively poor health conditions. The overall evaluation results indicate that neighborhoods with relatively poor health conditions are mainly distributed in the eastern part of the Shouyi area.

Subsequently, further detailed comparisons are made between the Qianjiajie neighborhood with better scores and the 719 neighborhood with lower scores. The results revealed that the differences in the quality of public spaces and facilities, as well as the level of social capital, are the reasons for the disparities in community health. Based on this, recommendations have been made, including increasing road network density, revitalizing public spaces, constructing green networks, and implementing digital management, all of which are applicable to the future development of post-pandemic communities.

Chapter 5: Discussion

5.1 The main changes of Urban planning's responses to pandemics

5.1.1. Study Themes and Identified Theories

The utilization of urban theories during the H1N1 and COVID-19 periods reflects a shift from singular to multifaceted approaches. Despite the emergence of "smart city" in 2010 coming after the H1N1 outbreak in 2009, matured theories like healthy cities (1986) and sustainability (1987) predated H1N1 but were conspicuously absent in H1N1-related studies. This absence underscores the substantial expansion of theoretical boundaries in urban planning during the COVID-19 period. Notably, no entirely new theories have surfaced in the current research on the COVID-19 pandemic; instead, there is an observable evolutionary synthesis rooted in multiple existing theories.Examining the breadth of the research field, urban theories such as "resilience," "sustainability," "smart cities," and "vulnerability" exhibit comprehensive coverage, proposing solutions across environmental, social, and economic dimensions within the complexities of COVID-19. The application of "smart cities" in urban governance stands out prominently (Sharifi et al., 2021), while "vulnerability" assumes a more significant role in the realm of socioeconomic factors (Gomez, 2022). Meanwhile, "sustainability" and "resilience" permeate all themes, with a particularly strong influence on the "Post-Covid planning" theme, signifying their theoretical leadership in shaping urban planning responses to future pandemics. Other urban theories receive comparatively less attention in pandemic response and are often confined to specific domains. For instance, the "15-minute city" exclusively focuses on the physical form of the city, specifically aiming to reduce the health burden associated with transportation through more compact land use patterns and proximity to services (Moreno et al., 2021).

While each urban theory maintains its distinct focus within specific study themes, keyword analysis results reveal substantial overlaps in their application, suggesting a trend toward the convergence of theoretical systems in urban planning responses to pandemics. For instance, the ICTs-based "smart city" theory proves instrumental in assessing the severity and scale of infection in the early stages of pandemics, aiding in the identification of areas with high

"vulnerability." The circular bio-economy model, rooted in the goal of "sustainability," can significantly alleviate strain on critical supply chains (e.g., food, personal protective equipment), aligning with the "resilience" theory's emphasis on the redundant characteristics of cities. Likewise, the "smart city" leverages key information technology to connect urban facilities and services, mitigating the negative impact on quality of life and contributing to the realization of a "livable city." "Tactical urbanism," "informal urbanism," and "temporary urbanism" offer concrete strategies for implementing locally-based adaptive governance, aligning with the principles of "resilience." Furthermore, the application of "sustainability" and "resilience" positively contributes to the concept of a "healthy city," particularly in terms of climate and environmental restoration measures, which also play a role in restoring people's mental health.

The crisis triggered by the coronavirus disease presents a new opportunity for disciplinary integration, fostering a diverse range of research perspectives and avenues for development. While quantifying the precise role of each urban theory in pandemic coping strategies remains challenging, it is evident that the intersection of multiple theories will become increasingly common in the future. Clarifying the interrelationships among different urban theories is expected to facilitate the combination and establishment of a more comprehensive and systematic response framework.

5.1.2. Comparisons of H1N1 and COVID-19 Responses

Change-1: from Stages of "in-Pandemic" and "Pre-Pandemic" to the Stage of "Post-Pandemic"

The co-occurrence analysis of keywords in the preceding section indicates that urban planning studies related to H1N1 were predominantly concentrated in the stages of "pre-pandemic" and "mid-pandemic." In contrast, studies related to COVID-19 were primarily centered around the "post-pandemic" stage. Early H1N1 studies (2009-2015) were intricately linked to the pandemic's outbreak and subsequent subsiding. Focusing on factors like visibility and transmissibility as key drivers of controllability (McCaw et al., 2014), numerous studies delved into modeling (Acuna-Soto et al., 2011), operating under the assumption that the situation would align with their preparedness plans. However, the

pandemic unfolded differently than anticipated, prompting critical reflection on the expectations set during the preparedness phase (Holmberg & Lundgren, 2018). Consequently, researchers sought to frame new preparedness plans by comparing existing strategies from various countries, aiming to enhance coordination for future pandemics (Liang et al., 2018). This transition characterized the late stage (2016-2019), shifting from "in-pandemic" to "pre-pandemic."

In contrast, research concerns during the COVID-19 period (2020-2022) manifested differently, reflecting a series of ideas and goals for the future city. Seventy-one papers explored how to minimize the impact of diseases and the likelihood of future pandemics, constituting 72% of the database. The disparity in the crisis scale between H1N1 and COVID-19 partly contributed to this difference. COVID-19 has resulted in over 6 million deaths worldwide as of today (WHO, 2020), whereas H1N1 caused less than 1 million deaths globally (Dawood et al., 2012). Additionally, the duration of the global health emergency, declared and ceased by WHO, was 16 months for H1N1 and 39 months for COVID-19. The assessment that the 2009 pandemic was mild (Bell et al., 2009) further underscores this distinction.

Empirical case studies from both periods reveal that consistent community mitigation measures, guided by the International Health Regulation (IHR), were adopted, including voluntary home quarantine, partial school and business closures, facemask orders, and, in some instances, stricter city-scale lockdowns during the COVID-19 period. The failure to control the COVID-19 pandemic prompted a profound reassessment within urban planning research of the occurrence and spread of infectious diseases in relation to the inner structure of cities, urban form, and urban ecology. Fundamental changes in urban development patterns were deemed crucial to preventing or mitigating the spread of infections. Consequently, COVID-19 became a catalyst for comprehensive reform in urban planning, leading to a renewed understanding of the relationship between human beings and the environment. The effects of COVID-19 spurred predictions of long-term, radical changes in urban planning (Acuto, 2020). Hence, the keywords during the COVID-19 period exhibited a

"post-pandemic" feature, even amid the ongoing challenges.

This contrast in research focus between the H1N1 and COVID-19 periods underscores that H1N1-related studies primarily addressed the operational aspects of preventing and reducing the spread of infectious diseases in the "pre-pandemic" and "mid-pandemic" phases, with minimal integration of urban theories. Conversely, the COVID-19 pandemic prompted a shift in research focus towards the "post-pandemic" dimension, leading to a more substantial integration of multiple urban theories and a higher prevalence of conceptual studies during this period compared to H1N1.

Change-2: From Global, National, to Local

The detailed analysis reveals a notable shift in the scope of studies between the H1N1 and COVID-19 periods. Most H1N1 studies were conducted on a national or regional scale, with minimal focus on individual cities. In contrast, during the COVID-19 period, the majority of studies targeted individual cities.

During the H1N1 pandemic, mathematical and computer models were globally employed for emergency response to infectious diseases, marking an initial foray into this approach (van et al., 2013). However, a significant challenge was the lack of real-time data availability, impacting the quality of pandemic predictions (Chambers et al., 2011). Retrospective assessments from the H1N1 era highlighted difficulties in high-performance computing and obtaining real-time data. Despite these challenges, collaboration between modelers and policymakers was facilitated, emphasizing the importance of evidence-based decision-making. By the time of the COVID-19 pandemic, advancements in artificial intelligence, big data, GIS, GPS, and other geospatial technologies enabled real-time monitoring and management. Data collection expanded beyond integrated national information systems to include civil society participation and self-reporting (Haraguchi et al., 2022). This diversified data landscape provided local managers with a more nuanced basis for decision-making and flexible pandemic response strategies, shifting the focus from national to local levels.

Theoretical development in urban planning was also evident. For instance, the term "Weberian city," a key urban theory keyword from H1N1 studies, was revisited in Hoffman's retrospective article (Hoffman, 2013). The critique of the 'all-hazards emergency preparedness and pandemic response' during H1N1 advocated for the revival of Weber's urban structure, emphasizing the importance of locality as a primary line of defense. The 2017 community mitigation guideline by the CDC incorporated lessons from the 2009 H1N1 pandemic, underscoring the significance of community acceptance and active participation in the timely and effective use of Non-Pharmaceutical Interventions (NPIs) (Qualls et al., 2017). The COVID-19 period witnessed the incorporation of the latest scientific evidence, recognizing the importance of local adaptability in the planning process (Li et al., 2021). Concepts like "tactical urbanism" and "informal urbanism" gained prominence, highlighting the value of bottom-up participation. Narratives related to "community resilience" suggested an empowerment of local communities, emphasizing the role of citizens (Xu et al., 2021). Experiences from various locations, such as Wuhan, Huangzhou, Urmia, Chicago, and Lombardy, emphasized that building urban resilience requires active public participation. Multi-sector, multi-level, and multi-stakeholder engagement emerged as essential, reducing reliance on technocratic bureaucracy and acknowledging the specificity of social and political dynamics. In summary, the transformation in governance patterns over the decade was shaped by both technical and theoretical preparations initiated during the H1N1 period. Robust data regulation and flexible multi-level governance are identified as crucial tools for cities to effectively navigate future pandemics.

Change-3: the Prominent Role of Urban Built Environment

The number of studies focusing on post-pandemic planning experienced a significant surge during the COVID-19 period compared to the H1N1 era, as highlighted in Table 2. A growing body of empirical cases illustrating the connection between the urban built environment and confirmed cases intensified research interest in this field. This extended from land use to building density, infrastructure layout to green space, all of which undergo changes over longer time spans. Such exploration of the "post-pandemic" realm during the COVID-19 era wielded the potent influence of the urban built environment in reinvigorating discussions

within urban planning and design, particularly in the context of public health.

Over the COVID-19 period, the trajectory of research on the urban built environment underwent notable shifts. Initial investigations probed how the coronavirus might influence the current urban landscape, particularly considering the potential lingering effects of social distancing, lockdowns, and border closures widely implemented in the early pandemic years (Mouratidis & Papagiannakis, 2021). While these effects are anticipated to diminish with the relaxation of pandemic policies, subsequent studies aligned with major urban theories under the post-COVID planning theme, suggesting enduring impacts on the built environment.

Firstly, the built environment became intricately linked with smart technologies. The successful integration of smart technologies during the pandemic prompted a substantial shift in residents' daily activities from offline to online, fostering the development of a distinctly different lifestyle post-pandemic (Pakoz et al., 2022). This necessitates positive changes in the built environment to accommodate this new way of life.

Secondly, the built environment's connection to sustainable development became pronounced. Critical reflections on urban land use, housing density, transportation structures, and food supply during the COVID-19 period not only curtailed the virus's spread but also enhanced resilience, improved air quality, and reduced energy demand. This, in turn, heightened the sustainability of the built environment, paving the way for a green path in post-pandemic urban development.

Lastly, the built environment intertwined with issues of vulnerability. The inequitable allocation of urban public space, services, and resources was identified as a significant contributor to vulnerability (Bin et al., 2021). Recognizing that unreasonable spatial distribution had a longstanding history, researchers sought to address this persistent problem hindering social equity by reorganizing and reallocating urban spaces.

Consequently, a continuous stream of research explored new urban models or forms, with

highly granular urban information and intelligent technologies serving as ideal testing grounds for incubating and applying theoretical blueprints (Moreno et al., 2021). Empirical combined modeling results emerged prominently during this period, hastening fundamental changes in the methodological and technical approach to urban planning and design.

In summary, studies under the Post-COVID planning theme may emphasize different aspects, but ultimately converge on the dimension of the built environment. This convergence is expected to pave the way for a new paradigm in urban planning and design, steering cities collectively toward health, inclusion, smartness, resilience, and sustainability in the near future.

5.2 The‘New normal’of neighborhood planning

The innovative solutions implemented across all community samples in the study reflect a positive response to the shifts in lifestyle dynamics. To tackle the surging delivery demands driven by online shopping, novel logistics spaces emerged, repurposing garages or integrating into the residential building's porch. These spaces effectively assumed the role of a "third party," ensuring safer transfers in the post-COVID-19 era. In response to the heightened need for outdoor activities, the surplus of underutilized spaces was repurposed. Residents, in a form of public ownership, either fully or partially, manifested these spaces through their behaviors.

Within the community, it becomes evident that changes in behavior, utilization, and duration outpace transformations in urban morphology. The most successful short-term adaptations seem to be facilitated by features such as flexible layouts, multifunctionality, space redundancy, and a sense of public ownership. However, the lingering question persists: are the converted neighborhoods destined to become our "new normal," or are they merely an amalgamation of temporary solutions?

5.2.1 Co-development of community space and logistics space

The emergence of inner commercial streets is perceived as a transient adaptation, expected to

wane as pandemic control policies relax, allowing people to extend their travels beyond the confines of neighborhoods. Nevertheless, COVID-19 has acted as a catalyst for enhancing the environmental quality of communities, aligning with the historical impact of pandemics (Budds, 2020; Chang, 2020). Essential services within the shopping street, like haircuts, should be permanently integrated into community plans. While non-essential services may face challenges in a more relaxed environment, the undeniable role of food and daily necessities in serving as a temporary resupply during closure periods remains crucial.

In contrast, the integration of logistics space with living space appears more assured in the future. Online lifestyles existed pre-pandemic, and COVID-19 has significantly expedited their evolution (Mouratidis & Yiannakou, 2022). The increasing reliance on online shopping has transformed courier delivery into a vital piece of urban infrastructure—a lifeline. The sustained presence of logistics spaces in communities has established a conduit for the "last mile" delivery of essential goods between the city and residents. Building on the success of "contactless delivery" practices, such as smart parcel lockers and posthouses, in mitigating virus spread, there is an imperative to explore new models for the future co-development of community spaces.

5.2.2 Self-sufficient and self-organizing building

The expansion or reconstruction of balconies and terraces, coupled with activities like children's games and rooftop vegetable planting, vividly illustrates residents' power to mobilize their initiative, instigating transformative changes in their environment. In the realm of limited space, residential buildings must exhibit the flexibility to adapt to diverse scenarios amid various stressors. Amidst the COVID-19 era, residences are no longer just homes; they serve as offices, schools, nursing homes, playgrounds, and even vegetable gardens. This multifaceted use challenges the conventional solidity of building functions, leading to a future where the boundaries between living, working, studying, and playing are further blurred.

Considering the constraints of building density, small-scale low-rise buildings possess the advantage of leveraging spatial flexibility more fully. In contrast, large-scale high-rise

buildings face limitations, especially in centralized renovations that are confined to the roof level. This presents new challenges for high-rise buildings in organizing additional free spaces. Looking ahead, the transformation of home spaces centered on healthy living and the reconstruction of public spaces to enhance neighborhood support are poised to become the focal points of future developments.

5.2.3 Neighbourhood co-governance

Many changes enacted by residents on the properties of a space through their behaviors are transient and temporary, like camping in a car park's green belt, subject to replacement by new ways of living. However, the community bonds forged through joint creation, use, and defense of space are enduring and robust. In the observed samples, successful public space transformations often stem from closely-knit communities with a shared desire to dismantle longstanding differences and barriers, ultimately effecting substantial space transformations.

These communities unite diverse stakeholders, including residents, property owners, residential committees, and enterprises. Their collective aspirations amid crises foster a strong, cooperative, and tacit co-governance model. Initially, residents support each other through neighborhood networks, engaging in group buying of food, mutual assistance for necessities, and more. Unmet needs are then bottom-up reflected to the community and 'identified'. Through 'joint design' and decision-making involving residents, properties, and social enterprises, guided by residential committees, more substantial human and material resources are mobilized for larger-scale improvements (e.g., the recreation of public spaces). Compared to top-down dispatch and planning, the co-governance mechanism proves adept at addressing emerging demands and fluid challenges, ultimately contributing to community safety and health.

5.3 The prediction of the vulnerable neighborhoods to the pandemics and future priorities

Based on the results of keywords analysis (Section 4.3), it is evident that study of neighborhoods under the impact of pandemic has undergone a notable evolution across

different phases. It has transitioned from purely epidemiological discussions to the analysis of the impacts of the built environment, subsequently leading to the formulation of models and concepts for post-pandemic urban design. Currently, there is a notable shift towards a greater emphasis on community organization and management. As the pandemic moved from inception, to outbreak, to recession, neighborhood research experienced a clear transition in emphasis from the physical environment to the socioeconomic, which can be viewed as the long-term impact of the pandemic on neighborhood planning.

As pandemic-related policies ease, and measures such as social distancing and closures become a thing of the past, the once-heated debate about urban density subsides, and the use of public transportation begins to pick up (De-Toledo et al., 2023). In 2022, the keyword "lessons" appears for settlement studies that directly reflecting on the COVID-19 pandemic, along with the keywords "politics", "local governance", "community resilience", and "justice" in 2023, none of which are linked to the physical urban environment, suggesting that lessons learned from the Coronavirus in the settlements are related to differences in governance and socioeconomic levels. Areas with high-quality housing tend to exhibit lower densities, often featuring more blue-green space configured around them, and well-maintained pedestrian and bicycle infrastructure - all of which contribute to the health of residents, especially during a pandemic. Conversely, in poorer neighborhoods, with limited resources, the opposite is often true. Inequities in community design stem from structural factors like decades of under-resourcing, demanding urgent attention.

Previous pandemics did not bring about any structural changes (Pinheiro & Luís, 2020), but there is reason to believe that COVID-19 pandemic will make a difference this time. Assessing the extent of the damage caused by modern viruses involves not only considering the impact on the size of the population stock but also whether human can return to its original state of life. In human history, there is no lack of pandemics that almost pushed human beings to the brink of extinction, but after the pandemic, human beings can still live and produce in the same way as before. COVID-19 is poised to be a watershed moment in pandemic history. Global economic structures are undergoing substantial restructuring, and

residents are unlikely to return to their pre-pandemic lifestyles. The decline of traditional industries, the ascent of the digital economy, and the accelerated process of intelligentization have led to widespread acceptance of telecommuting, online education, and Internet healthcare, and their awareness of environmental protection and health and safety has further increased. Consequently, neighborhood planning structures have accepted, with the emergence of new working spaces (Zenkteler et al., 2023), the revitalization of green and public spaces (Cheung et al., 2022), the implantation of intelligent infrastructure (Hassankhani et al., 202), the trend of suburbanization (Li & Wei, 2023), and increased resident participation in community affairs (Stender & Nordberg, 2022). These adjustments align with evolving lifestyles, making people to face a variety of active and passive choices about their neighborhoods, all of which greatly challenge the established norms. This situation not only offers an opportunity for resource reallocation but also poses a risk of further exacerbating inequality due to the disparity in socioeconomic status of neighborhoods and the existence of the digital divide. The changes brought about by COVID-19 are therefore a double-edged sword. In the medium to long term, there is a pressing need for leveraing wisdom and science to reevaluate the value of health and life. Emphasizing the role of community management in promoting social equity is crucial, along with the prompt development of neighborhood institutions adapted to the new way of life.

On this basis, the establishment of the Post-pandemic Neighborhood Health Evaluation System is of great significance. Different from the existing neighborhood health evaluation system, it innovatively introduces new evaluation factors, such as the number of outdoor facilities based on family space, the proportion of home-based workers, the level of digital management of the community, etc., which comprehensively and accurately aligns with the new residential lifestyle in the post-pandemic era. It can help government managers and urban planners quickly identify residential areas with health risks, while objectively highlighting differences in the health levels among residential areas. In this way, not only will they be well prepared for the next outbreak, but also maximize social inclusion and equity.

Through empirical case studies in Wuhan, this study further proposes the main priorities for

neighborhood planning in the post-pandemic context with respect to the following three principles, 1) new changes and themes brought about by the COVID-19; 2) serving as bridges to establish links between the social and physical aspects of neighborhoods; 3) possessing the ability to act swiftly to reduce inequalities between neighborhoods at a lower cost and in a shorter period. That is, factors explored next are prioritized by this study as they satisfy all three of these conditions simultaneously.

---Social capital

As the neighborhood factor that received the most attention in the current debate, revealing its significant influence on population health from the pandemic perspective. Social capital generally refers to the sum of resources or capabilities mobilized through social networks (Israel & Feder, 2023). At the community level, social capital encompassess the networks of relationships that people form in their communities and the resources embedded in those networks. A growing body of research reveals that neighborhoods with higher social capital have higher levels of population health and health equity.

While the COVID-19 crisis has generated extensive discussions about factors in the physical environment of neighborhoods, global-scale results show disparate outcomes in similar neighborhood environments (e.g., the same high-density environment) (Liu et al., 2021). The variance in outcomes is attributed to resident reactions, individual and group behaviors, and the implementation of control measures, i.e. the social capital of the neighborhood largely changed the results of the pandemic. This also demonstrates that management may be more effective than urban planning in the face of infectious diseases, in a way that questions traditional urban planning that relies on the transformation of the physical environment.

In fact, community social capital is intricately connected to the physical environment of the neighborhood. On the one hand, it significantly influences the provision of resources for the physical environment of neighborhoods. Communities with high level of social capital are likely to pay more attention to landscaping and greening. During the pandemic, community social capital can also be used to enhance interaction between residents through innovative

use of public housing, inefficient public land, and motor vehicle parking spaces; and to create a strong network of relationships that builds trust within the community, which can be transformed into special public resources (e.g., sanitation supplies, amenities, etc.) that are urgently needed in the midst of an pandemic. On the other hand, community social capital profoundly influences the use of the neighborhood's physical environment resources. Finucane et al., (2022) referred to the exclusion of disadvantaged groups from the public open spaces in the neighborhood, not because of physical accessibility, but because of the segregation tactics that some inhabitants adopt towards others. The same is true for the reference to the fact that local public services are not accessible to specific groups because of racial discrimination (Pflugeisen & Mou, 2021). Thus, even with enhanced walkable blue-green spaces, public spaces and localized services are built, it will still be futile without strengthening social capital.

Social capital plays a pivotal role in building community-minded social networks and establish values encompassing norms of equality, trust, cooperation, reciprocity and sharing (Liu et al., 2023). The altruism of providing resources to other and social cohesion ultimately makes collective mutual aid possible to overcome the situation together. Community managers, on the other hand, create "problem-centered" governance on their own terms by working with health care providers and other stakeholders or by fully associating actors such as associations, volunteers, etc. (Turcu & Rotolo, 2022). Actively utilizing their strengths, they efficiently address crises, finding breakthroughs and innovative strategies in corners that the government failed to reach.

Special priority should thus be given to the protection and nurturing of social capital in future neighborhoods. Strengthening the impact of community social capital on the physical environment is crucial for achieving flexibility in delivering critical public resources and services, ensuring equity for all. Additionally, there should be a shift in how local governments and communities collaborate, moving away from centralized governance models toward strategic partnerships. Further decentralization of grassroots organizations, transparent information channels, and inclusive opportunities for residents to participate in neighborhood

governance are essential. These efforts aim to build trust and support among residents and government and between residents themselves, maximizing preparedness for public health emergencies.

---Health-oriented tactical design strategies

Social isolation measures implemented during the pandemic have reshaped established social behaviors of residents and altered their use of space. Consequently, communities that are closest to their daily needs are called upon to apply more resilience-based, adaptive spatial models (Slade, A, 2023). This is manifested in the reshaping of public open space systems, as well as multifunctionality, and a temporal correlation with the functions that the space can accommodate. Examples include the temporary closure of motorways, the expansion of bicycle networks, the widening of sidewalks, and the repurposing of parking lots and other crevice spaces into active living, play, and social spaces. Such transformations in settlements - understood as 'tactics' (Lydon & Garcia, 2015) - promote a dilution of the boundaries between private and public space, encouraging safer active transportation. These temporary initiatives reconfigure community spaces according to localized needs, raise awareness and build solidarity, proving more conducive to fostering children's creative practices (Pfeiffe et al., 2022), achieving age-friendliness (Mariano et al., 2022), and reintroducing the needs of vulnerable groups (e.g., disabled people, ethnic minority) visible again (Hassen, 2021), ultimately advancing neighborhood equity.

However, this is still seen as a short-term emergency measure. How to permanently incorporate valuable changes remains a problem. Given that most previous planning has been top-down, prescribing neighborhood environments and organizing activities, tactical urbanism can complement bottom-up concepts and perspectives. Serving as a bridge, it establishes an effective link between the social needs of neighborhoods and the shaping of built environment. When the pandemic created new social demands, it resulted in a new time allocation, spatial layout and intensity of space use for the daily behavioral activities of people within the settlement. Understanding the intentions behind the residents' active transformation of space can provide important clues for future reshaping of the spatial and temporal structural

relationships related to activity behavior. In the case of neighborhoods in poor condition, the numerous missing spaces and services cannot be quickly filled in a short period of time. Hence, it is necessary to consider the functional arrangements and attributes of the sites adjusted or corrected during the pandemic as a permanent regularization of the changes. For example, lost spaces located in or around the corners of the neighborhoods, which were temporarily used as public activity spaces during the pandemic, should be considered for permanent adoption and conversion to increase public well-being. These types of small-scale, low-cost, flexible design strategies can quickly help realize the justice needs of vulnerable residents. Given the limitations of individual agency and, special attention should be paid to innovations at the structural level, to rethink the community engagement process towards equity-based placemaking. In future community building, it is necessary to return to public entities as facilitators of interventions, encouraging the active participation of residents and combining it with the activation of creative and innovative experiences with a strong social impact. Testing such interventions in the form of pilots on a local and/or regional scale, and considering the rapid replication of successful experiences and models.

---Digital preparedness and solutions

Digital preparedness plays a crucial role in disaster management today. The COVID-19 experience shows that digital technologies are one of the main planning tools for reducing population risk and vulnerability. It can significantly alleviate urban dysfunction, thereby improving community well-being (Hassankhani et al., 2021). From the perspective of urban planning, scientific and technological means, encompassing communication technology and big data, have improved the different stages of crisis management. In addition, the participation of residents has been increased to varying degrees, and the transparency of government processes and social connections have been improved. In particular, the deployment of technologies in healthcare, education, and employment systems has enhanced the resilience of residents to maintain basic living functions.

However, the pandemic has also laid bare the prevalence of the digital divide at the neighborhood level. In neighborhoods with advanced economies and clear advantages in

information technology, the tendency to digitize aspects of life and work has become more pronounced. Individuals in these areas meet their daily needs through online office work, online shopping, online food ordering and online learning. In contrast, neighborhoods with weak internet connections or no internet coverage at all are excluded from the array of services available online. Residents with lower levels of education are less likely to access telework opportunities, elderly residents may lack the skills to use online services, and residents from diverse linguistic or cultural backgrounds may face challenges in participating in online services.

The pandemic has accelerated the process of digitalization, and there is a great potential for the digital dividend to reach neighborhoods once impenetrable to physical resources and services. This offers new directions and possibilities for achieving social equity. Consequently, there is an urgent need for more research on inequalities in the distribution of technology in order to find initiatives and practical solutions. These solutions include universal access to every household in the community, ensuring internet connectivity in public spaces such as community centers, providing training and empowerment programs for users in utilizing digital technologies, and maintain the provision of complementary offline services.

Chapter 6: Limitation

Due to difficulties in obtaining data and limitations related to professional fields and research levels, the scope of selection for evaluation indicators is limited and has certain constraints. In subsequent research, it is necessary to broaden the scope of thinking and conduct a more scientific and comprehensive analysis of the selection of evaluation indicators.

This study selected eight residential areas in the Shouyi area of Wuchang District, Wuhan City, as case studies. However, due to the serious aging population in the Shouyi area located in the old urban area of the city, the population samples have certain uniqueness. The digital lifestyle in post-pandemic era, such as flexible remote work, could not provide sufficient sample data for research, which had a certain impact on the health assessment results. In future research, efforts should be made to expand the research scope to include diverse residential area samples and improve the accuracy of data collection for relevant indicators. The optimization strategy for healthy post-pandemic neighborhoods goes far beyond what is mentioned in this paper. The construction of healthy neighborhoods is a challenging and ongoing task that requires joint efforts from all sectors of society and multidisciplinary support. Further research and improvement should also be conducted in future studies.

Chapter 7: Conclusions

Health is an eternal topic, especially with the occurrence of the COVID-19 pandemic, which has prompted more urban planning scholars to focus on addressing the pandemic and improving residents' health. Due to the long duration and wide-ranging impact of this public health emergency, its effects on cities are profound. This study, standing in the context of the post-pandemic era, conducts an in-depth analysis of the development trends of urban planning under the influence of the pandemic. Based on this background and foundation, it summarizes the long-term factors affecting community health under the pandemic's influence and constructs a corresponding evaluation index system based on theoretical and empirical research. Finally, it evaluates and proposes relevant optimization strategies using a sample from the Shouyi area of Wuhan, China. The main research conclusions of this paper are as follows:

- Establishment of the main trends and directions of urban planning under the pandemic's influence:

The study reviews the origins of urban planning in public health, the development of healthy cities, and the comparative analysis of urban planning responses and performances during major outbreaks. It determines that under the backdrop of the COVID-19, urban planning is returning to the theme of health, with a growing emphasis on localization and digitization trends.

- Clarification of the main changes in neighborhoods under the pandemic's influence:

Based on sample data through long-term questionnaire collection, field visits, and surveys, it was found that the pandemic has had a considerable impact on residents' lifestyles. Specifically, it has led to online functions replacing offline activities, a reduction in daily travel distances, an increased demand for natural and outdoor spaces, as well as expanded participation in community development. Neighborhoods have made corresponding changes in response to these changes, including adaptive functions in residential buildings, integration of logistics spaces, and deepening of community autonomy. These changes herald the arrival

of a new era of healthy neighborhoods in the post-pandemic era.

- Construction of a post-pandemic evaluation system and indicators for healthy neighborhoods:

By focusing on the long-term impact of the pandemic on neighborhoods, the study has identified 40 specific indicators across four dimensions: physical, environmental, demographic, and socioeconomic, constructing an evaluation system for healthy neighborhoods in the post-pandemic era. Special attention has been paid to including indicators reflecting the long-term impact of the pandemic on neighborhood construction, including the scale of shared spaces, the proportion of flexible office/home office workers, and the level of community digital management. Using the Shouyi area in Wuhan, China as an example, it evaluates the overall health results of its current neighborhoods based on the evaluation system and visualizes them. By comparing neighborhoods with better and poorer health conditions, the paper proposes optimization strategies from the perspectives of road design, public space, and community management. These experiences can help similar cities quickly identify vulnerable neighborhoods and make adequate preparations for the next outbreak.

Chapter 8: Scientific Findings

As a conclusion, the scientific findings of the PhD program are summarized as follows.

Finding 1

Pandemics have not affected cities for the first time in human history. Looking back, frequent crises have deepened the understanding of urban planning in responding to infectious diseases. At present, however, most studies have focused on the single outbreak of COVID-19, and there is a lack of research into the latest developments in urban planning responses to pandemics with historical retrospective. To fill this gap, by reviewing the major global public health crises, I found that there have been two pandemics as defined by the WHO of this century: the COVID-19 pandemic and the 2009 H1N1 pandemic. To clarify the main changes in between, I employed bibliometric analysis and detailed analysis to explore which urban planning theories or models were used in response to the two pandemics and how they evolved through the past decade, predicting the future trends.

Based on Keyword co-occurrence analysis overlaid with time in VOSViewer (Figure.1), I found that among the 139 keywords, 45 were related to H1N1, while the other 94 were related to COVID-19, which showed the color transition from cold to warm (representing the time transition from the year 2010 to 2020). It is notable that keywords related to H1N1 focused more on protocol phases such as virus ‘transmission’, ‘intervention’ methods, and ’preparedness’ for pandemic planning. The application phase of the H1N1 study stayed in the ‘mid-pandemic’ and ‘pre-pandemic’ tenses, while COVID-19, on the other hand, focused more on the ‘post-pandemic’ outcome, exploring how to build more desirable cities (especially in terms of management and environment) through a number of studies linking pandemic to urban techniques and theories.

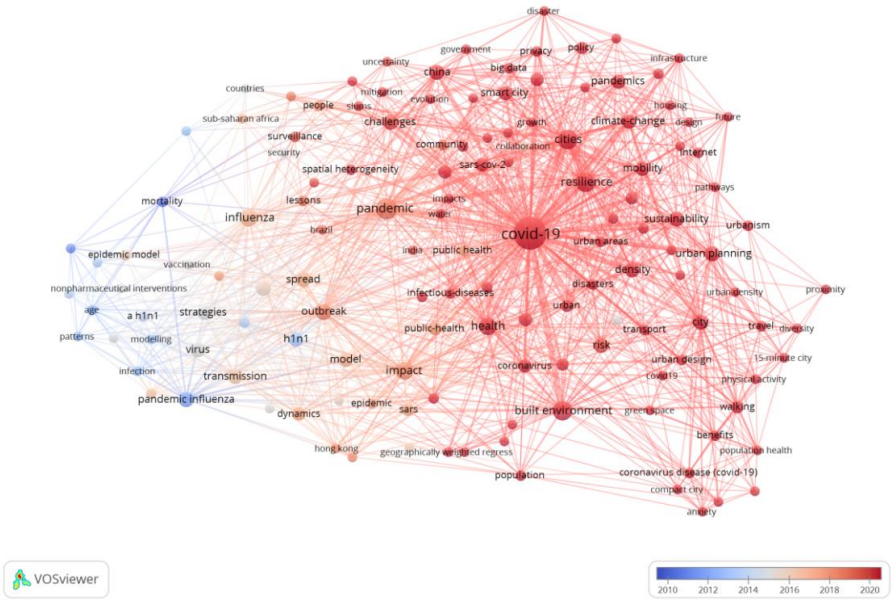


Figure 1. Keywords Analysis of H1N1 and COVID-19 review overlaid with time

By detailed analysis of the geographic scope in the selected papers, I realized that the H1N1 period was mostly studied on global, national or even regional basis, with less than 1/3 of the studies on urban scale. On the other hand, most of the study subjects of the COVID-19 period became individual cities, accounting for 79% of the total number of targeted articles. There were more city-based even neighborhood-level case studies, including New York, London, Chicago, Madrid, Bogota, Hong Kong, Wuhan, Tehran, etc.

Table 1. Percentage and keywords of articles per study theme of the included papers.

			Occurrence of Urban Theory Keywords												
Study Theme	**Group**	**Percentage (%)**	**Resilience**	**Smart Cities/City**	**Sustainability**	**Vulnerability**	**Healthy City**	**15-min City**	**Compact city**	**Temporary Urbanism**	**Informal Urbanism**	**Tactical Urbanism**	**Livable City**	**Weberian City**
Governance policy	H1N1	57				1								1
	COVID	13	3	6	1									
Built environment	H1N1	0												
	COVID	10	2		1									
Modeling	H1N1	33												
	COVID	10	1		1		1							
Socioeconomic factors	H1N1	10												
	COVID	32	5	1	1	4			1					
Post COVID planning	H1N1	0												
	COVID	35	9	5	5	1	2	3	1	1	1	1	1	
Total	H1N1					1								1
	COVID		20	12	9	5	3	3	2	1	1	1	1	

By using information synthesis mentioned, I further found all recorded literature can be classified into five specific themes, which are: (1) governance and policy; (2) built environment; (3) modeling; (4) socioeconomic factors; and (5) post-COVID planning (Table.1). The target articles on H1N1 topics were distributed in concentrated areas, with 57% on ‘governance and policy’ and 33% on ‘modeling’while studies on COVID-19 covered a wider range. Especially, studies on future-oriented urban planning rose sharply, accounting for 35% of the overall included articles, while no relevant records existed in the H1N1 era. A comparable situation occurred in the built environment area, where the target article contribution rate reached 10%, achieving another zero breakthrough. And I also discovered that the association of H1N1-related research with urban theories was rare, with the author keywords ‘vulnerability’ and ‘Weberian city’ appearing once each in the theme of governance and policy. On the contrary, complex and diverse urban theories emerged from COVID-19-related urban planning studies. It was most widely distributed in the area of post-COVID planning, covering 11 urban theories which include: (1) ‘resilience’, (2) ‘sustainability’, (3) ‘smart city’, (4) ‘vulnerability’, (5) ‘healthy city’, (6) ‘15-min city’, (7) ‘tactical urbanism’, (8) ‘temporary urbanism’, (9) ‘informal urbanism’, (10) ‘Compact city’, and (11) ‘livable city’, of which the first four are the most widely used and most important.

Last but not the least, I detected that multiple urban theories appear together in the authors’ keywords, in which the terms ‘resilience’ and ‘smart cities’ and ‘resilience’ and ‘sustainability’ appear most frequently together. Additionally, ‘resilience’ and ‘vulnerability’, ‘smart cities’ and ‘tactical urbanism’, ‘sustainability’ and ‘livable city’ suggest that these theories have overlaps in providing effective prevention and control pathways for pandemics. By clarifying the interrelationship among different urban theories, it is expected to combine and establish a more complete and systematic response framework.

Finding 2

From October 2020 to February 2023, I used three typical types of neighborhoods (traditional/work-unit/gated-community) in Wuhan as the empirical case studies in observing the actual changes brought by the pandemic to the settlements. Through comparative analysis including random questionnaire, participant observation, in-depth interviews and multi-party workshop, I examined the key shifts in the lifestyle of Wuhan residents before and after COVID-19 and discovered how neighborhoods responded to the changes.

By data collected from online questionnaire through snowball sampling using social network (N=949 individuals, aged 18-83 years), I found that the online activities including shopping, working, learning and entertaining all increased compared to pre-COVID-19 period (Figure.2). The biggest changes lied in online learning and working, with 29.5% and 59.8% of respondents said they had never worked and learned online before COVID-19 dropped sharply to 7.3% and 37.2% respectively after. Taking into account that 13.5% of the participants were from the 65+ age group who did not use electronic devices regularly, I therefore analysed separately for only the senior group, and I found that those who chose the "sporadically" and "occasionally" options for online shopping surged to 213% of that in pre-COVID-19 time, confirming that elderly citizens living alone can hardly survive in extreme pandemic conditions without internet. In a sense, COVID-19 made the online lifestyle not just the icing on the cake, but a necessity.

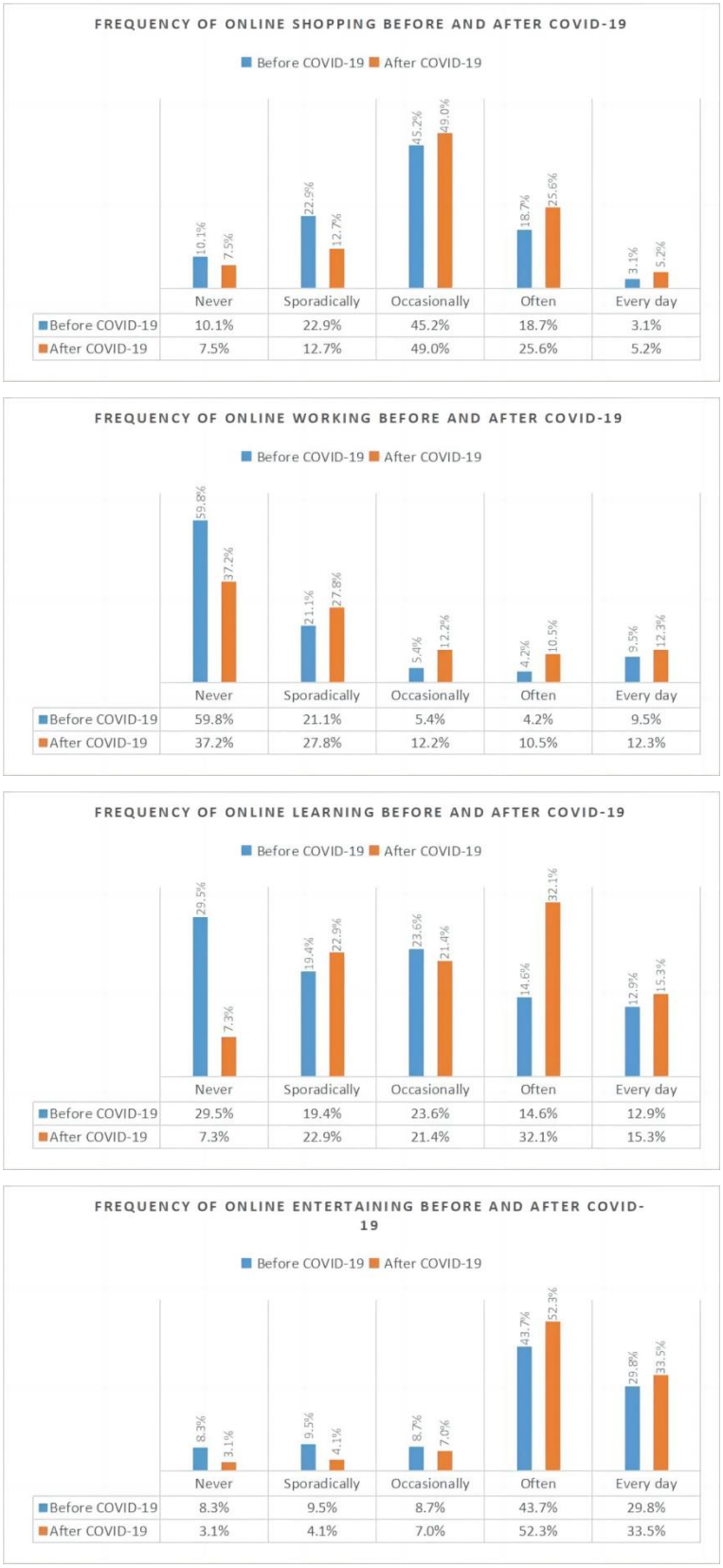


Figure 2. Frequency of online activities before and after COVID-19 in Wuhan.

Additionally, I discovered that the importance of community green space, community garden, community fitness facilities(outside), ground for sports(outside) also increased after COVID-19 (Figure.3). On average, the most important public space before and after COVID-19 was community green space, followed by ground for sports. Significant rise in importance was reported for community garden (45.5% increase), while the increases in the importance of community fitness facilities(outside) was considerably smaller (16.1% increase). The popularity of community garden in the aftermath of the COVID-19 outbreak might also be linked to food shortages during the lockdown, as the results of the questionnaire also showed that 17.1% of respondents grew plants (including vegetables) on their balcony or terrace while 6.7% tried to grow plants for the first time after COVID-19, showing a great enthusiasm for gardening. On contrary, the importance of community activity center(inside) saw markedly reduced (26.9% reduced). Similar reduction (11.1% reduced) was also recorded in community fitness facilities(inside). The rise in the importance of outdoor public spaces was accompanied by a decline in the importance of indoor public spaces. Overall, the results suggested that outdoor and green public spaces were preferable in post-COVID-19 time.

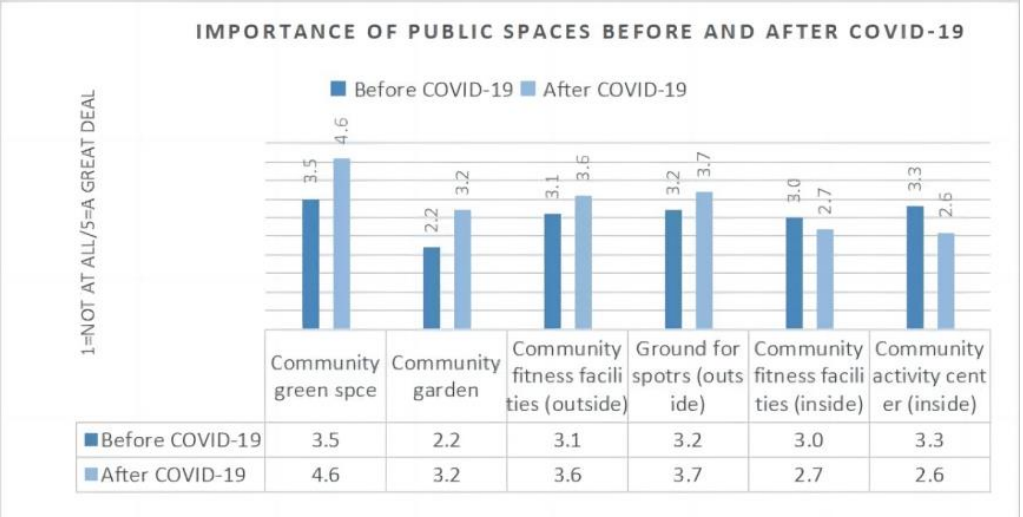


Figure 3. Mean values of importance of spaces before and after COVID-19.

Moreover, I detected that people's daily travel range narrowed down considerably. In Figure 4, for example, 52.6% of respondents sought medical treatment within 15-30 minutes of travel before COVID-19. While the proportion decreased to 34.1% after and almost half of people surveyed (45.9%) chose to travel within 15 minutes for doctors.

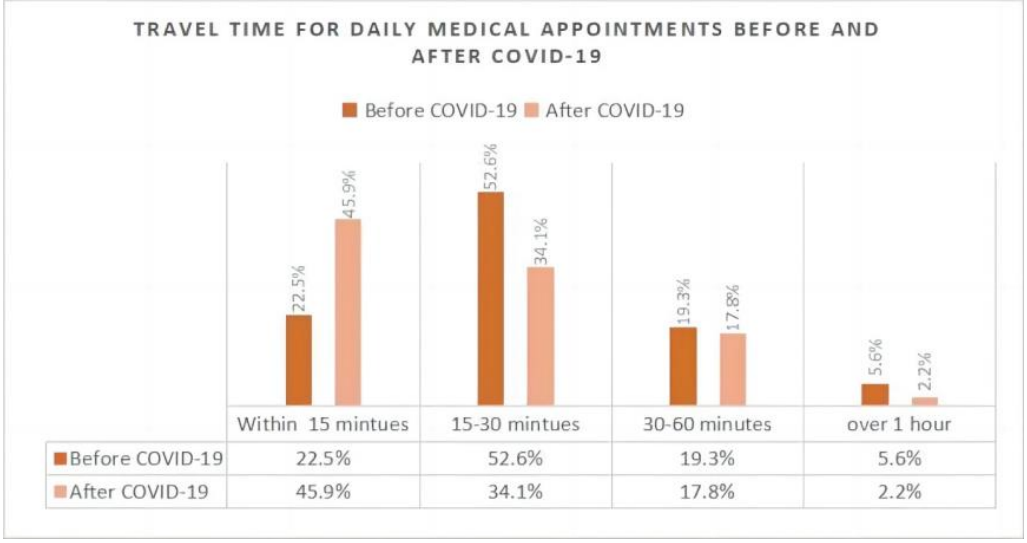


Figure 4. Travel time for medical appointments before and after COVID-19.

Through nearly two years of volunteers' behavior dairies, regular interviews with residential committee and monthly field investigation, I discovered that changes took place in all three neighborhoods. In terms of the range of changes, the three showed a striking consistency, all concentrated at the microscopic-scale adjustments on ground floor layer, roof layer and outdoor layer. In total, 4 logistics stations, 1 enlarged waterfront green space, 2 roof gardens, 9 sports grounds, 21 small shops, 7 informal public spaces were added, and 15 examples of self-renovation of houses had been found, providing a glimpse of how quickly settlements were responding and adapting to the changing lifestyles (Figure.5). And Table.2 presents a attempt at cataloging neighborhood changes of all samples. By intensive verification and discussion with multiple actors, I further confirmed that the embedding of logistics spaces, self-sufficient buildings adapting to multiple scenarios and co-governance considered to be effective forms of neighborhood in the post-pandemic era.

Figure 5. Maps showing the locations of changes of neighborhoods in Wuhan.

Table 2. Change list of Vanke, Gonglu and Eryao communities from Feb.2021 to Feb.2023

Spatial dimension	Specifics of the changes	Neighborhood in which it appeared	Earliest emergence	Subjects of participation	Corresponding changes	Long term(L) VS Short term(S)	Qualities supporting public health in pandemic	Features affecting public health
Ground floor	Increase of touchless smart lockers	1/2/3	2021.5	Property; Enterprise	1	L	Encourage contact-free behaviour to reduce the spread of the virus	Impromptu response/ Adaptive behaviour Filling the gaps in provision within the community
	Increase of posthouses	1/2	2021.4	Self-employed	1	L		
	Increase of temporary tables or shelves at the entrances when the community was closed	1/2/3	2021.7	Property	1	S		
	Garage rental to commercial tenants, being transformed into various small shops(haircut/bakery/milk station...)	1/2	2021.8	Owners; Self-employed	3	S		
	Addition of terrace or roof layer	1/3	2021.3	Owners	2	S		
Roof	Added sky garden	1/2	2021.4	Owners	2	L	Physical and mental health benefits	Self-sufficiency in extreme circumstances Multiple and adaptive uses
	Rooftop playground for children	1/2/3	2021.6	Owners	2/3	S		
Outdoor	Parking lot transformed into public space	1/3	2022.3	Owners	2	S		

Increase of outdoor sports venues (ping pong table/basketball hoop/badminton court...)	1/2	2022.1	Property; Residential committee; Enterprises	2	L	Reuse of redundant space
Neighbour chatting or chess and cards with mobile furniture	1/2/3	2021.4	Owners	2	S	Impromptu response/ Adaptive behaviour
Tent setters appear on the greenbelt	1	2022.3	Owners	2/3	S	

Note: Neighbourhood 1= Vanke 2=Gonglu 3=Eryao, Change 1=Strengthening trend towards online activities 2=Expanding demands for green and outdoor spaces 3=Proximity choices in daily activities.

Finding 3

Current studies shed light on the association between neighborhoods and COVID-19, but most research has focused on the short-term effects during its outbreak. There is a lack of research on the longer-lasting changes that persist after the initial stages of the pandemic. The primary factors influencing neighborhood health in the post-pandemic era remain unclear.

Therefore, I filled the gap by firstly conducting a literature research between 2020 and 2023 on neighborhood planning under the impact of the COVID-19 pandemic. I searched and screened articles on three databases: Web of Science, Scopus, and PubMed. Following the principles of systematic review, keywords analysis (by CiteSpace for keyword co-occurrence and burst detection) and detailed analysis were employed to generate the required results. The keywords analysis helped to understand the evolution and trends of neighborhood research under the influence of pandemics throughout the years. Then detailed analysis was applied to categorize among the neighborhood risk factors extracted from the literature and pair them with physical health, mental health, and health equity outcomes, respectively.

From the results of keyword co-occurrence analysis by CiteSpace (see in Figure.6), I found that‘accessibility’ in 2021 emerged as a bridge, linking the prior appearance of ‘infrastructure’ with the subsequent words like ‘parks’, ‘social inequality’, and ‘15-minute city’, which implies that within the pandemic context, research on neighborhood areas progressed from a broad focus on infrastructure to a subsequent emphasis on green spaces, delving into uncovering the relationship between accessibility and social inequality, ultimately leading to discussions about new urban models. Following that, ‘mental health’ emerged as a bridge connecting the preceding research keywords ‘depression’ to the subsequent ‘space’, ‘urban design’, and the recent additions of ‘affordability’ and ‘old adults’. This progression indicates the evolution of research from phenomena exploration to built environment analysis and attributing socioeconomic variables. Another important node in 2021, ‘green infrastructure’, jointly connected ‘accessibility’ and ‘mental health’, demonstrating its intermediary role between the two. The turning point in 2022 appeared with ‘urban health’, linking ‘human’, ‘adult’,‘female’,‘food insecurity’, and subsequently, ‘land use’, ‘stakeholder’, ‘local

government' and 'politics'. This highlights recent research determination in proposing health-promoting solutions, particularly emphasizing organizational management aspects.

From the detailed analysis of the included literature, I summarized a total of 40 factors that have been shown to be relevant to the health of neighborhoods in the post-pandemic perspective. Notably, the physical dimension emerges as the most impactful, encompassing 23 factors. The environmental dimension contains 3 factors, the demographic dimension involves 9 factors, and the socioeconomic dimension includes 5 factors.

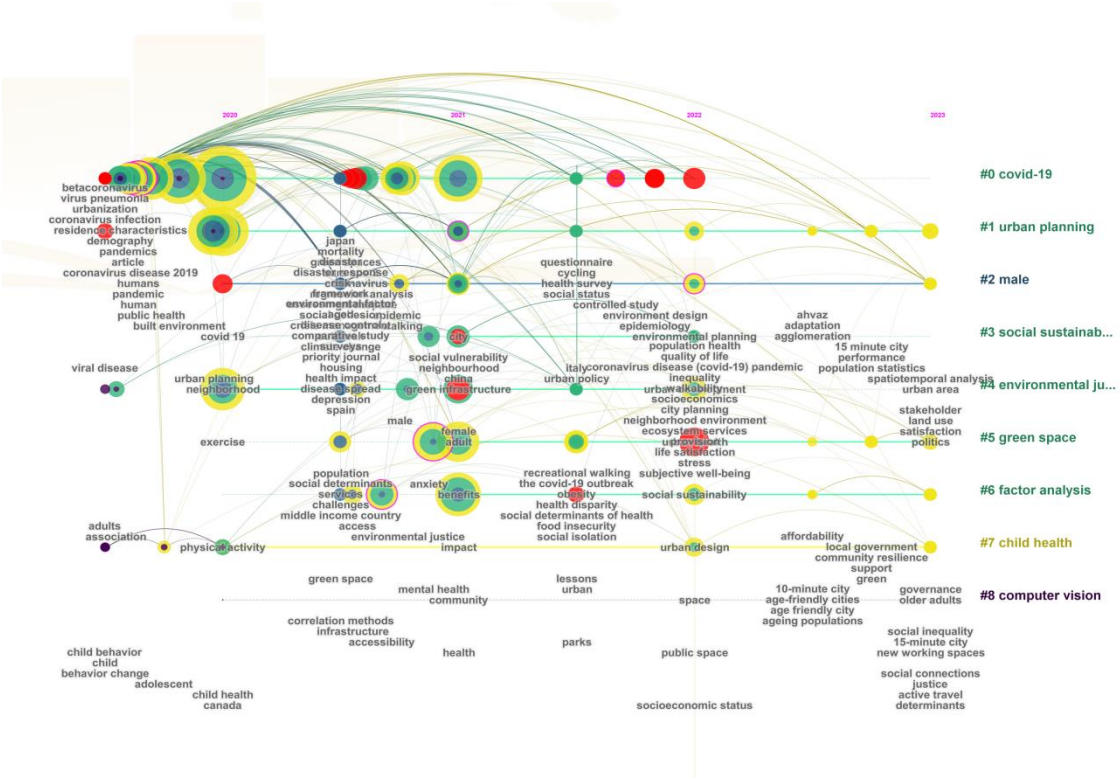


Figure 6. Co-occurring keywords timeline from 2020 to 2023 in CiteSpace

Then, I attempted to explore the correlation between the factors of neighborhoods and the ability of prevention and control of infectious diseases, providing an integrated assessment framework for post-pandemic neighborhoods in the case of Wuhan (Figure.7).

Figure.7 Urban district of Wuhan, China

Among the 40 indicators of the included literature, 35 indicators were regarded as suitable for measuring neighborhood health in the specified context of Wuhan, as the updated data for five indicators were not accessible for further analysis. Thus, these factors affecting the health of neighborhoods in the post-pandemic period were finally selected, including 19 physical, 3 environmental, 8 demographic, and 5 socioeconomic factors. Then, I designed survey questionnaires and interviewed experts in relevant fields. I utilized the Likert 5-point scale (0 for no impact, 1 for low impact, 2 for moderate impact, 3 for high impact, and 4 for very high impact) to determine the direct influence relationships between indicators. I collected raw data through questionnaire surveys to construct the initial impact matrix MD among assessment indicators. Next, I standardized the initial direct impact matrix MD to obtain the comprehensive impact matrix MT. I then employed the Analytic Network Process (ANP) hierarchical structure algorithm and utilized Super Decision v2.6.0 software to calculate the weighted supermatrix. After stabilizing the weighted supermatrix, I finally obtained the limit relative ranking vector W*.

W*=（W1*，W2*，…Wn*）=（0.0404，0.0367，0.0398，0.0328，0.0280，0.0311，0.0175，0.0420，0.0036，0.0123，0.0106，0.0081，0.0315，0.0267，0.0345，0.0471，0.0104，0.0208，0.0249，0.0412，0.0096，0.0312，0.0440，0.0415，0.0405，0.0332，0.0140，0.0376，0.0321，0.0362，0.0151，0.0337，0.0245，0.0356，0.0316）Overall, this process allowed for the assessment of the weights of each indicator, as shown in Table 3.

Table 3. Impact dimensions and weighting of indicators

Levels of influence and weighting	Risk factors	Global weight	local weight
Physical	Built-up density	0.0404	0.091
	Outdoor assets	0.0367	0.078
	Living space per person	0.0398	0.075
	Land-use mixture	0.0328	0.07
	Density of commercial land	0.0280	0.082
	Residential greenery	0.0311	0.086
	Scale of public open space	0.0175	0.081
	Scale of local services	0.0420	0.076
	Scale of urban farming and community garden (for food)	0.0036	0.081
	Scale of primary medical facilities	0.0123	0.077
	Number of hand washing facilitators	0.0106	0.097
	Scale of sharing spaces (i.e. co-working space)	0.0081	0.105
	Distance to the city center	0.0315	0.176
	Amount of walking/cycling facilities	0.0267	0.118
	Accessibility to public transit	0.0345	0.133
	Accessibility to blue and green space	0.0471	0.154
	Accessibility to public open space	0.0104	0.146
	Accessibility to infrastructures of healthcare	0.0208	0.15
	Accessibility to local services	0.0249	0.124
Environmental	Exposure to air pollutants (PM10, NO2, NO)	0.0412	0.365
	Capacity of wastewater surveillance	0.0096	0.308
	Capacity of Solid waste management(SWM)	0.0312	0.327
Demographic	Percent of Poverty	0.0440	0.123
	Population density	0.0415	0.129
	Percent of Female	0.0405	0.123
	Percent of Low education level （Below high school）	0.0332	0.126
	Percent of Aging population (over 65)	0.0140	0.115

	Percent of Home-based workers	0.0376	0.141
	Household size	0.0321	0.119
	Percent of population with pre-existing chronic diseases or other health issues	0.0362	0.124
Socioeconomic	Social capital (i.e. community engagement and citizen participation)	0.0151	0.25
	High property fee	0.0337	0.212
	Social cohesion and Social trust	0.0245	0.173
	Residential stability	0.0356	0.161
	Digital preparedness and solutions	0.0316	0.204

Based on the evaluation system constructed above, I obtained data for indicators in four dimensions: physical, environmental, demographic and socioeconomic. Due to differences in dimensions, large variations in mean values, and the lack of relevant standards for some indicators, it was not possible to assign specific quantified scores to each indicator. Therefore, using the natural breaks method in GIS software, I classified each group of indicators into five categories from high to low. For positive indicators, values of 1, 2, 3, 4, and 5 were assigned sequentially, while for negative indicators, the values were assigned in reverse.

According to the way of assigning points to each indicator combined with the weights determined in Table.4, I finally evaluated the target neighborhoods. After statistical analysis, the scoring results of the 18 neighborhoods were classified into the following four categories: healthy neighborhood (3.620-4.222), relatively healthy neighborhoods (3.029-3.619), relatively unhealthy neighborhoods (2.250-3.028), and unhealthy neighborhoods (1.912-2.249). See details in Figure.8.

I further compared the neighborhoods with higher scores to those with lower scores and found that they share similarities in terms of building density and layout. However, the main reasons for the health disparities lie in the quality, scale of public spaces and facilities, and level of social capital.

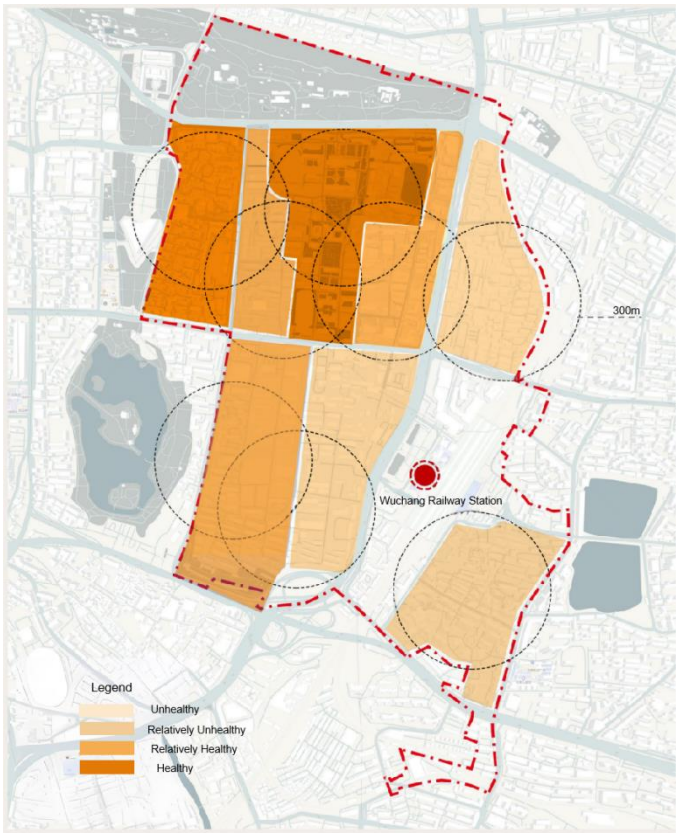


Figure 8. Results of the health rating in targeted districts

Appendixes

Appendix A. Questionnaire on the impact of COVID-19 on residents' lives

Dear fellow citizens,

Hello! We are research team of "Post-pandemic City and Neighborhood" from university of Pecs and now sincerely inviting you to take an active part in this survey.
The following topics are for us to understand how the COVID-19 pandemic affected residents' lives. Please select each level that matches you and tick the corresponding option. In the third part of the survey on lifestyle before and after the pandemic, we need you to recall the specific situations before and compare them with after. The data collected in this questionnaire is for research purposes only, and no information will be leaked. Thank you for your support!

Part I: Basic information

1. How old are you?
□ under 18
□ 18-25
□ 26-30
□ 31-40
□ 41-50
□ 51-60
□ above 60

2. Your gender is
□ Male
□ Female

3. Your education level is
□ primary school
□ middle school
□ college or University
□ graduate and above

4. The neighborhood you live in

_____

Part II: General impression

5. Which of the following matches your general feeling during the outbreak
□ anxiety and impetuous
□ happy and optimistic
□ no change from usual
□ there are good and bad
□ other cases

6. What do you think of the pandemic response in your neighborhood (nucleic acid testing, material distribution, closure and control policies, etc.)
□ overall very satisfied
□ overall satisfied
□ overall not satisfied
□ overall very dissatisfied

7. What's the least satisfying aspect of your neighborhood during the outbreak?
□ transportation
□ public space
□ medical treatment
□ shopping, culture and leisure
□ management
□ other

Part III: Living situation

8. Before the pandemic, how did you work/study...?
□ online
□ offline

9. Before the pandemic, how did you commute?
□ public transport
□ by private car
□ by bike or on foot
□ don't go out much

10. Before the pandemic, how did you buy food?
□ online
□ offline

11. Before the pandemic, how did you seek medical treatment?
□ online
□ offline

12. Before the pandemic, how did you meet family and friends?
□ online
□ offline

13. Before the pandemic, how did you do your leisure activity?
□ online
□ offline

14. Before the pandemic, when you were doing outdoor activities, which of the following places did you mainly do your activities?
□ plaza or street space near the community
□ exclusive activity space (such as children's activity space, fitness activity space, etc.)
□ natural space (park or suburb)
□ no outdoor activities

15. After the pandemic, how did you work/study...?
□ online
□ offline

16. After the pandemic, how did you commute?
□ public transport
□ by private car
□ by bike or on foot
□ don't go out much

17. After the pandemic, how did you buy food?
□ online
□ offline

18. After the pandemic, how did you seek medical treatment?
□ online
□ offline

19. After the pandemic, how did you meet family and friends?
□ online
□ offline

20. After the pandemic, how did you do your leisure activity?
□ online
□ offline

21. After the pandemic, when you were doing outdoor activities, which of the following places did you mainly do your activities?

□ plaza or street space near the community
□ exclusive activity space (such as children's activity space, fitness activity space, etc.)
□ natural space (park or suburb)
□ no outdoor activities

22. Has the pandemic affected how often you go to public spaces?
□ almost no effect
□ has a certain impact, reducing the frequency of going to public spaces
□ almost no longer go to urban public spaces

23. Has the outbreak affected your frequency of travel to nature-based spaces?
□ almost has no effect
□ has a certain effect, increasing the frequency of going to nature-based spaces
□ has a certain effect, reducing the frequency of going to nature-based spaces
□ never gone to natural space

Part IV: Living quality

24. How satisfied were you with the livability of the community environment?
□ very satisfied
□ quite satisfied
□ generally satisfied
□ relatively dissatisfied
□ very dissatisfied

25. What is the overall environment of your residential space?
(Score 1-5 from poor to good/small to big/low to high...) [matrix scale questions]

	1	2	3	4	5
General situation	□	□	□	□	□
Number of households	□	□	□	□	□
Building density	□	□	□	□	□
Outdoor facilities	□	□	□	□	□
Community management	□	□	□	□	□

26. How satisfied were you with the convenience of the community facilities?
□ very satisfied
□ quite satisfied
□ generally satisfied
□ relatively dissatisfied
□ very dissatisfied

27. In your opinion, the facilities that can be added in the community are

_____.

28. How did you feel about studying/working from home? (If not applicable, you can skip this question)
□ dislike studying/working from home
□ have to study/work from home but can adapt
□ very adaptable to home study/work
□ like to study/work from home very much, consider normalizing it

29. Which space in your home would you most like to change?
□ kitchen
□ living room
□ bedroom
□ study
□ balcony/terrace
□ garden
□ garage
□ other

30. What was your greatest expectation for the office space?
□ closer to home or integration of home space
□ complex function (fitness, entertainment, shopping integration)
□ more green space

31. You feel that among the following environmental factors the most helpful one for you to stay healthy during the pandemic is _____, followed by_____, then _____, and finally _____.
A.lower building density
B. accessible natural environment
C. sufficient outdoor facilities
D. excellent city organization and management

32. How did you feel about the relationship between neighbors during the pandemic?
□ very good
□ good
□ general
□ poor
□ very poor

33. How satisfied were you with the community in providing special care for vulnerable groups?
□ very satisfied
□ quite satisfied
□ generally satisfied
□ relatively dissatisfied

□ very dissatisfied

34. How satisfied were you with the participation of residents in the community in public affairs for pandemic response and control?

□ very satisfied
□ quite satisfied
□ generally satisfied
□ relatively dissatisfied
□ very dissatisfied

35. Have you considered moving out of the neighborhood?

□ yes
□ no

36. In order to better safeguard the health of the population, your suggestions for neighborhood in the post-pandemic period are

_____.

Appendix B. The risk factors mentioned by included studies and their associated health outcomes.

Reference (Year)	Risk factors associated to health outcomes		
	Physical health	Mental health	Health equity
Sun et al., (2023)			Accessible to blue and green space
Brooks et al., (2023)	Capacity of wastewater surveillance		
Rajoo et al., (2021)		Frequency of community park/garden use	
Sharma et al., (2023)	Capacity of wastewater surveillance		
Hubbard et al., (2021)		Poverty/ Accessible to public open space/ Accessible to blue and green space/ Female/ Aging	
Adhikari et al., (2020)	Poverty/ Minority racial/ethnic populations		
Li et al., (2020)	High density of commercial land/ Accessible to public transit/ land-use mixture/ Aging population		
Yang et al., (2022)		Frequency of community park/garden use/ Walking/Cycling facilities	
Debucquet et al., (2022)		Urban farming and community garden (for food)	
Kato & Matsushita (2021)	Walking/Cycling facilities		
Paköz et al., (2021)	Accessible to public open space		
Smith et al., (2023)	Walking/Cycling facilities/ Accessible to	Walking/Cycling facilities/ Accessible to	

	blue and green space/ Social cohesion and Social trust	blue and green space/ Social cohesion and Social trust	
Izuhara et al., (2022）	Social cohesion and Social trust	Social cohesion and Social trust	
Liu et al., (2021)	Social capital		
Israel & Feder (2023)			Social capital
Pfeiffer et al., (2022)	Health-oriented tactical design strategies		
Das et al., (2021)	Capacity of Solid waste management(SWM)		
Mouratidis, (2022)	High built-up density/ Accessible to public transit / Limited living space per person/ Residential greenery/ Local services	High built-up density/ Accessible to public transit/ Limited living space per person/ Residential greenery/ Local services	
Mouratidis & Yiannakou (2022)	Accessible to blue and green space/ Local services/ High built-up density/ Proximity to city center/ Limited living space per person	Accessible to blue and green space / Local services/ High built-up density/ Proximity to city center/ Limited living space per person	
Song et al., (2023)			Poverty
Li et al., (2023)			Minority racial/ethnic populations
Frumkin (2021)	High built-up density/ Exposure to air pollutants (PM10, NO2, NO)/ Minority racial/ethnic populations/ Poverty		
Ismail et al., (2022)	Residential greenery	Residential greenery	
Säumel & Sanft (2022)	Residential greenery	Residential greenery	
Boza-Kiss et al., (2021)			Poverty/ Digital preparedness and solutions
Harlem (2020)	Limited living space per person/ Education level/ Accessible to		

	infrastructures of healthcare/ Population with pre-existing chronic diseases or other health issues		
Huang (2023)	Urban farming and community garden (for food)	Urban farming and community garden (for food)	
Zenkteler et al., (2022)	Home-based workers		
Finucane et al., (2022)	Minority racial/ethnic populations	Minority racial/ethnic populations/ Walking/Cycling facilities	Minority racial/ethnic population
Marcelo et al., (20220	Accessible to public open space	Accessible to public open space	
Liu et al., (2022)	Social Capital/ Digital preparedness and solutions		
Chen et al., (2023)	Exposure to air pollutants (PM10, NO2, NO)/ Capacity of wastewater surveillance/ Public open space/ Residential greenery/ Social capital/ Digital preparedness and solutions		
Mousavinia, (2023)		Courtyard housing layout	
Spennemann, (2021)	Residential greenery	Residential greenery	
Wolday & Böcker (2023)	Outdoor assets/Accessible to public transit	Outdoor assets/ Accessible to public transit	Outdoor assets/ Accessible to public transit
Mariotti et al., (2022)	Sharing spaces (i.e. coworking space)		
Kashem et al., (2021)	Low education level		
Egerer et al., (2022)	Urban farming and community garden (for food)	Urban farming and community garden (for food)	
Radomskaya & Bhati (2022)	Accessible to public open space / Social	Accessible to public open space/ Social	

	capital	capital	
Zhu & Holden (2023)	Residential stability/ Local services/ Accessible to local services	Residential stability/ Local services/ Accessible to local services	
Asfour (2022)	Gated community		
Mouratidis (2021)	Accessible o infrastructures of healthcare/ Access to local services/ Walking/Cycling facilities/ Accessible to public transit / Accessible to blue and green space/ Accessible to public open space / Limited living space per person/ Outdoor assets/ Digital preparedness and solutions	Accessible to infrastructures of healthcare / Access to local services / Walking/Cycling facilities /Accessible to public transit/ Accessible to blue and green space / Accessible to public open space/ Limited living space per person /Outdoor assets/ Digital preparedness and solutions	
Che et al., (2023)	Local services		
Kan et al., (2021)	High built-up density/ High density of commercial land /Land-use mixture		
Zetterberg et al., (2021)	Social capital		
Kato et al., (2021)	Walking/Cycling facilities		
Gurram et al., (2022)	High population density		
Huang et al., (2021)	High built-up density/ High density of commercial land		
Cabrera-Barona et al., (2023)	Accessible to public open space/ Social cohesion and Social trust	Accessible to public open space/ Social cohesion and Social trust	Accessible to public open space/ Social cohesion and Social trust
Landgrave-Serrano & Stoker (2023)	Pedestrian or Bikeway connectivity		
Olivier et al., (2023)	Accessible to infrastructures of		

	healthcare		
Tayebi et al., (2022)	Amount of local facilities /Walking/Cycling facilities/ Accessible to public open space/ Accessible to infrastructures of healthcare		
Sun & Lu (2020)		Social capital	
Zenkteler et al., (2022)	Home-based workers		
Buffel et al., (2023)			Aging population / Poverty
Tharak et al., (2022)	Capacity of wastewater surveillance		
Hejazi et al., (2023)	High built-up density		
Wang et al., (2021)	High population density		
Beiler & Ren (2021)	Walking/Cycling facilities		
Zhang (2021)	Aging population		
Habibullah (2022)	Accessible to public open space		Accessible to public open space
Joshi & Wende (2022)	Urban farming and community garden (for food)	Urban farming and community garden (for food)	
Gür (2022)	Poverty		Poverty
Chen et al., (2023)	High Property fee		
Cheung et al., (2022)	Public open space/ Accessible to public open space	Public open space/ Accessible to public open space	Public open space/ Accessible to public open space
Guida & Carpentieri (2021)	Accessible to infrastructures of healthcare		
Wash et al., (2022)	Local services	Local services	Local services
Liu & Wang (2021)	Accessible to blue and green space	Accessible to blue and green space	Accessible to blue and green space
Jackson et al., (2023)	Social capital		Social capital

Samus et al., (2022)		Outdoor assets	
Huerta, (2022)	Accessible to blue and green space		Accessible to blue and green space
Paköz et al., (2022)	High population density		
Ma et al., (2023)		Walking/Cycling facilities/ Residential greenery/ Social cohesion and Social trust	
Lehberger et al., (2021)		Outdoor assets/ Residential greenery	
Sun & Lu (2020)		Social capital	
Joseph et al., (2020)	Minority racial/ethnic populations/ High built-up density		
Horak & Vanhooren (2023)	Social cohesion and Social trust	Social cohesion and Social trust	
Jato-Espino et al., (2022)		Accessible to blue and green space	
Verma et al., (2021)	Poverty		Poverty
Lak et al., (2021)	High population density/ High density of commercial land/ Accessible to public transit		
Di Marino et al., (2023)	Sharing spaces (i.e. coworking space)		
Song et al., (2021)	Accessible to public open space/ Local services	Accessible to public open space/ Local services	
Xie & Shao, (2022)	Social capital		
Naseri et al., (2023)	Walking/Cycling facilities		
Zanganeh et al., (2022)	Poverty/ Aging population		
Hong & Choi (2021)	Land-use mixture/ Aging population		
Bojović et al.,	Health-oriented tactical		

(2022)	design strategies		
Iida et al., (2023)	Urban farming and community garden (for food)	Urban farming and community garden (for food)	
Hananel et al., (2022)	Minority racial/ethnic populations		
Venerandi et al., (2023)	High built-up density		
Yang et al., (2021)	Residential greenery		
Larson et al., (2021)	Poverty/ Minority racial/ethnic populations		Poverty/ Minority racial/ethnic populations
Altay & Şenay (2023)	Local services	Local services	
Gubić & Wolff (2022)	Accessible to blue and green space		
Samuelsson et al., (2021)	Accessible to blue and green space		
Yeager et al., (2021)	Capacity of wastewater surveillance		
Slingerland et al., (2023)	Social capital		
Choi & Denice (2022)	Limited living space per person / High density of commercial land / Walking/Cycling facilities/ Poverty/ Residential greenery		
Di Marino et al., (2023)	Home-based workers		
Ferhati et al., (2023)	Social Capital/ Accessible to green and blue space		
Fezi (2020)	Land-use mixture/ Public open space/ Local services / Sharing spaces (ie. coworking space)/ Walking/Cycling facilities		
Frank & Wali (2021)	Walking/Cycling facilities/ Residential greenery		
Gaisie et al.,	High built-up density/		

(2022)	Land-use mixture/ Walking/Cycling facilities		
Giorgi et al., (2021)	Public open space/ Social cohesion and Social trust/ Sharing spaces (ie. coworking space)	Public open space/ Social cohesion and Social trust/ Sharing spaces (ie. coworking space)	
Gu et al., (2023)	Minority racial/ethnic populations/ Poverty		Minority racial/ethnic populations/ Poverty
Hassen (2022)	Minority racial/ethnic populations/ Poverty/ Social capital		Minority racial/ethnic populations/ Poverty/ Social capital
Hess & Bitterman (2023)	Walking/Cycling facilities		
Hino & Asami (2021)	Social capital		
Jiao et al., (2021)	Female/ Aging population/ Accessible to blue and green space		
Lak et al., (2021)	Minority racial/ethnic populations/ Poverty		Minority racial/ethnic populations/ Poverty
Lee et al., (2022)	Poverty		
Li et al., (2023)	Accessible to local services/ Accessible to infrastructure of healthcare/ Accessible to blue and green space/ Local services		
Liu et al., (2021)	High population density/ Limited living space per person/ Public open space		
Liu et al., (2023)	Social capital		
Ma et al., (2022)		Poverty/ Accessible to blue and green space/ Social trust and cohesion	
Mariano et al., (2022)	Public open space/ Health -oriented tactical design strategies		
Mehta (2020)	Health-oriented tactical		

	design strategies		
Mitra et al., (2020)	High population density/ Accessible to blue and green space		
Murayama et al., (2021)	Social capital		
Nguyen et al., (2020)	Land-use mixture/ Walking/Cycling facilities/ Minority racial/ethnic populations/ Low education level		
Oh et al., (2022)	Minority racial/ethnic populations/ Aging population/ Poverty/ Big household size		
Al Omari et al., (2023)	Accessible to public open space		
Palm et al., (2021)	Walking/Cycling facilities/ Accessible to infrastructures of healthcare/ Accessible to public open space/ Accessible to local services		
Quaglio et al., (2021)	Outdoor assets/ Health-oriented tactical design strategies		
Ribeiro et al., (2021)		Accessible to blue and green space/ High frequency of community park/garden use/ Residential greenery	
Santinha et al., (2023)	Social capital		
Sardeshpande et al., (2021)	Urban farming and community garden (for food)	Urban farming and community garden (for food)	
Schinazi et al., (2022)	Social capital	Social capital	Social capital
Harumain et al., (2023)	Walking/Cycling facilities	Walking/Cycling facilities	
Shentova et al., (2022)		Residential greenery	

Slabaugh et al., (2022)			Health oriented tactical design strategies
Slade (2023)	Health-oriented tactical design strategies		
Smith et al., (2023)	Walking/Cycling facilities/ Accessible to blue and green space/ Social capital	Walking/Cycling facilities/ Accessible to blue and green space/ Social capital	
Turcu et al., (2022)	Social capital		
Ugolini et al., (2020)	Accessible to blue and green space/ Residential greenery	Accessible to blue and green space/ Residential greenery	
Hamurcu & Yılmaz (2023)	Residential greenery/ Land-use mixture/ High density of commercial land		
Wali et al., (2023)	Walking/Cycling facilities		
Wang et al., (2022)	Walking/Cycling facilities/ Poverty/ Minority racial/ethnic populations		
White et al., (2022)	Social capital		
Xiao et al., (2022)		Outdoor assets/ Accessible to blue and green space	
Zenkteler et al., (2023)	Sharing spaces (i.e. coworking space)		
Zhang et al., (2022)	Accessible to blue and green space		
Zhang et al., (2022)	High built-up density		
Chunara et al., (2021)	Minority racial/ethnic populations/ Digital preparedness and solutions		Minority racial/ethnic populations/ Digital preparedness and solutions
Hassankhani et al., (2021)	Digital preparedness and solutions	Digital preparedness and solutions	
Adkins-Jackson et al., (2022)	Social capital		
Sepúlveda-Loyola et al., (2020)	Aging population / Social capital	Aging population /Social capital	

Witham et al., (2020)	Social capital		
Litt et al., (2023)	High Frequency of community park/garden use	High Frequency of community park/garden use	
Lee et al., (2021)	Social capital	Social capital	
Lewin et al., (2021)	Primary medical facilities		
Gilmore et al., (2020)	Social capital		
Gillies et al., (2022)	Big household size		
Chiam et al., (2022)	Social capital		
Suleimany et al., (2022)	Social capital/ Accessible to public open space/ Local services/ Social cohesion and Social trust/ Residential stability	Social capital/ Accessible to public open space/ Local services/ Social cohesion and Social trust/ Residential stability	
Pflugeisen & Mou (2021)	Minority racial/ethnic populations		
Li & Mou (2022)	Minority racial/ethnic populations/ Female		
Tabrizi & Lak (2023)	Accessible to public transit/ Walking/Cycling facilities/ Accessible to blue and green space/ Accessible to public open space	Accessible to public transit/ Walking/Cycling facilities/ Accessible to blue and green space/ Accessible to public open space	Accessible to public transit/ Walking/Cycling facilities/ Accessible to blue and green space/ Accessible to public open space
Lahariya (2020)	Primary medical facilities	Primary medical facilities	Primary medical facilities
Yang et al., (2023)			Accessible to local services/ Accessible to public transit/ Accessible to blue and green space
Edelman et al., (2021)	Primary medical facilities		Primary medical facilities
Qin et al., (20230	Minority racial/ethnic populations		
Maidment et al., (2021)	Accessible to infrastructures of		Accessible to infrastructures of

	healthcare		healthcare
Jewett et al., (2021)	Social cohesion and Social trust	Social cohesion and Social trust	
Ezezika et al., (2023)	Handwashing facilitators		Handwashing facilitators

Appendix C. The Questionnaire on health factors in neighborhoods under the influence of pandemic (expert scoring)

The purpose of this questionnaire is to determine the relative weights among the influencing factors affecting the health of settlements in the context of the impact of the post-pandemic situation. The questionnaire was designed according to the analytical network method (ANP) format. This method involves a two-by-two comparison of the importance and degree of interaction of the influencing factors at the same level. The scale is divided into nine levels, where the values of 9, 7, 5, 3, and 1 correspond to absolutely important/strong, very important/strong, important/strong, slightly important/medium, and equally important/very weak, respectively, and 8, 6, 4, and 2 indicate that the level of importance and interaction is between the two neighbouring levels. The rank cells to the left indicate that the left column factors are more important than the right column factors, and the rank cells to the right indicate that the right column factors are more important than the left column factors. Just click on the appropriate cell according to your view. The cells will change colour when clicked, identifying your judgement data for this two-by-two comparison.

Sample table: What is the relative importance of the following two-by-two comparison elements for the health of settlements in the post-epidemic period?

A	Comparison of importance																B
Built-up density	◀ 9	◀ 8	◀ 7	◀ 6	◀ 5	◀ 4	◀ 3	◀ 2	1	2 ▶	3 ▶	4 ▶	5 ▶	6 ▶	7 ▶	8 ▶	9 ▶	Scale of public open space

Sample table: How strong is the connection between the two factors for the neighborhood health in the post-pandemic period?

A	Comparison of importance									B
Built-up density	■ 9	■ 8	■ 7	■ 6	■ 5	■ 4	■ 3	■ 2	■ 1	Scale of public open space

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