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degree of PhD in Architecture Engineering

Post-pandemic Urban Planning:

Innovations in Cities and Neighborhoods

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1. Introduction

"Some events are so big that they divide the world into before and after, into present and the alien past. Wars do this, and pandemic does it too" (Nixey, 2020).

The sudden outbreak of the COVID-19 pandemic at the end of 2019 is a major global health crisis. According to the latest WHO data available (from October 2023), the pandemic of COVID-19 has exceeded 6 million deaths from 400 million cases in the world (WHO, 2023). This huge number is not only a wake-up call for urban development and health and safety, but also has far-reaching implications for global endeavors. Public health emergencies have put a global spotlight on the interaction between public health events and human survival. The World Health Organization (WHO) published the top ten threats to global health in 2019, and infectious-related diseases accounted for six of them (WHO, 2019). It can be seen that public health is gradually becoming a new threat compared to the previous unhealthy behavioral habits of individuals.

Unsurprisingly, cities have again been the epicenters of the pandemic, with over 90 percent of COVID-19 cases occurred in urban areas (UN, 2020). All sorts of problems exploded in the cities: shortages of medical resources, disruptions in transport and logistics, poor risk communication, and uneven spatial distribution of infrastructure (Ibert et al., 2022), all of which made it clear that urban planning is crucial for better public health and for mitigating people's vulnerabilities to various hazards (UN, 2020).

Looking back into history, public health crises have had a significant impact on the evolution of urban planning and design concepts and approaches (La Greca et al., 2020). The COVID-19 pandemic has also brought a renewed interest in expanding on adaptive planning, urban layout, urban morphologies which can make for a healthier living. Existing research has increased our understanding of the pandemic's transmission and control dynamics, allowing us to reflect on urban planning, design, and management concepts (Jevtic et al., 2021). However, most studies have focused on the single outbreak of COVID-19, and there are fewer historical retrospective studies, especially concentrated on the latest changes in urban planning's response to pandemics, which can predict new urban planning developments. Meantime, whereas the impact of the pandemic is still ongoing and exceptionally profound, having changed the way individuals and communities live, work and interact (Mouratidis & Papagiannakis, 2021). In particular, the pandemic has compressed the temporal and spatial distances over which residents travel, making settlements the sphere of their daily activities (Moreno et al., 2021). Community-based prevention and control has since become an important line of defense in controlling the spread of infectious diseases today and in the future. Its built environment and organizational system directly affect on the city's ability to prevent, respond to and recover from infectious disease outbreaks. However, empirical studies compiling such evidence are scarce as the majority of studies focused on short-term changes during the outbreak. Studying the long-term impacts of pandemics on cities and neighborhoods and collecting the latest physical and non-physical evidence in favor of the health of residents will be of great benefit to us, as they offer essential input on shedding light on a more green, inclusive, and resilient urban planning.

Wuhan, the city used as the case study in the thesis, is located in central China and is home to more than 11 million people. As the first city to have an outbreak and experienced lockdown over two months, it becomes a suitable case for examining the impact of the post-pandemic lifestyle. This statement briefly introduce my Wuhan-based research during these five years spanning the pandemic. The results of the study could fill the gaps in the research described above, by exploring the new concepts that connect the nexus of urban planning and public health, and providing insight into the implications of the COVID-19 pandemic for urban planning, particularly in terms of long-term, sustained trends in how cities and neighborhoods can improve the population's well-being in the post-pandemic era.

2. Aim of the research

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, which is summarized in the following three points:

2.1 By historically reviewing and comparing the differences between COVID-19 and previous outbreaks, an attempt was made to identify"*What changes have recently taken place in urban planning in response to pandemics?*" Meantime, it seek 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, or techniques, which presents future trends. It offers the very foundation for the later steps of the study.

2.2 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, an attempt was made to explore "*How does the COVID-19 pandemic influence on the neighborhood planning? Which are the emerging risk factors with substantial evidence in influencing health outcomes from a post-pandemic perspective?* "

2.3 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*.

3. Research methodology

To achieve the aim, this study is mainly divided into three major research methods (See Figure.1). Firstly, it starts with literature review to summarize relevant information as the entry point for the research. Secondly, primary data is obtained through questionnaires and field surveys to provide a data foundation for the study. Thirdly, analysis methods constructed in SPSS matrices and quantified in ARCGIS

spatially are employed to provide a strong basis for optimizing the research strategy.

3.1 Literature Review: Summarizes urban studies related to the COVID-19 pandemic from both theoretical factors and research methods aspects. It delineates research directions, progress, and the long-term impacts and trends brought to urban planning and residential planning by the COVID-19 pandemic. Particularly, it clarifies the main factors and related variables affecting residents' health under the new situation, providing theoretical support for constructing post-pandemic residential models.

3.2 Field Research: Data on built environments, community management, and operation are obtained through field research. Typical communities in Wuhan are selected for on-site mapping, object interviews, workshops, etc., to acquire first-hand data from various research areas.

3.3 Quantitative Analysis: Relevant data obtained through field research and big data are statistically organized. Based on the selection and modification of candidate indicators affecting health by experts, this study uses a comprehensive method integrating Decision Laboratory Analysis (DEMATEL) and Analytic Network Process (ANP) to construct a comprehensive impact matrix and network relationship model. It objectively describes the characteristics of the interaction and influence of various factors in the evaluation system and calculates the weight of each indicator. Finally, empirical cases are analyzed to objectively assess the pandemic prevention capabilities of various residential areas, identify deficiencies in post-pandemic neighborhoods from objective technical indicators, and propose solutions.

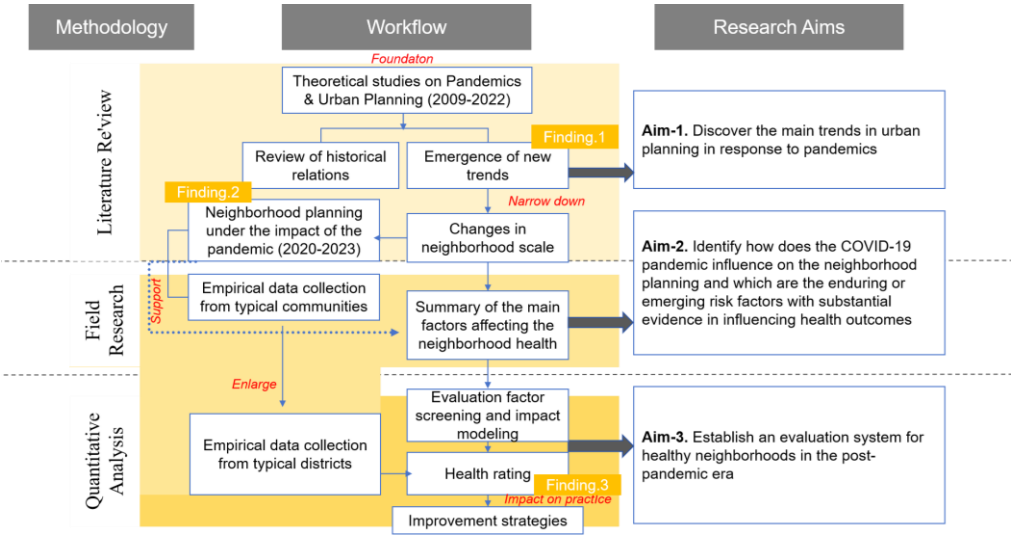

Figure 1. Research framework

4. Principal findings

Finding 1

Tu & Reith, (2023), [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.

1.1 Based on Keyword co-occurrence analysis overlaid with time in VOSViewer (Figure.2), 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.

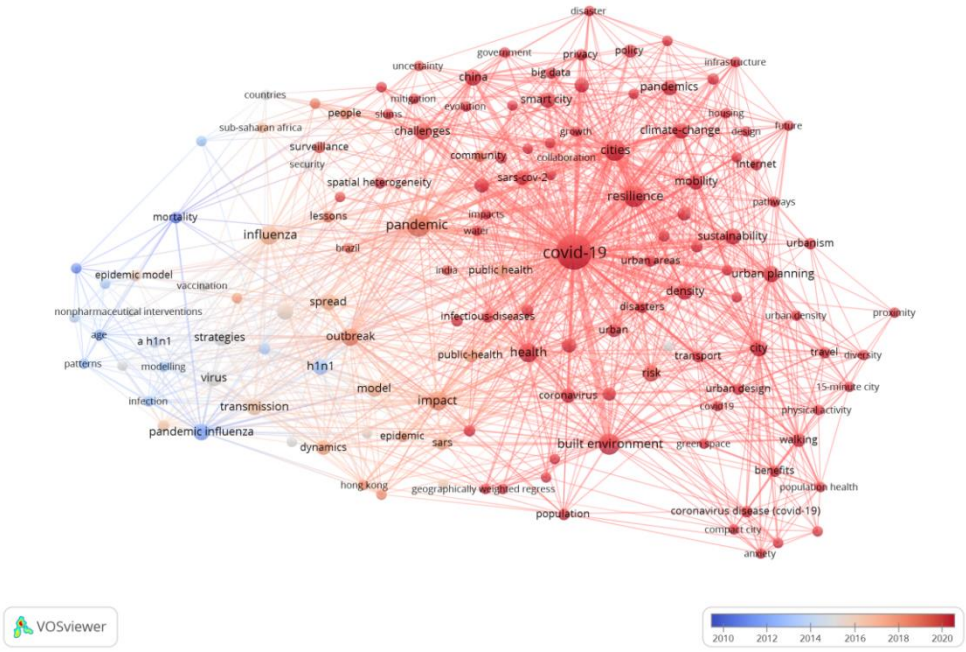

Figure 2. Keywords Analysis of H1N1 and COVID-19 review overlaid with time

1.2 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.

1.3 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.

			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	

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

1.4 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

Tu & Reith, (2023), [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.

4.1 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.3). 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.

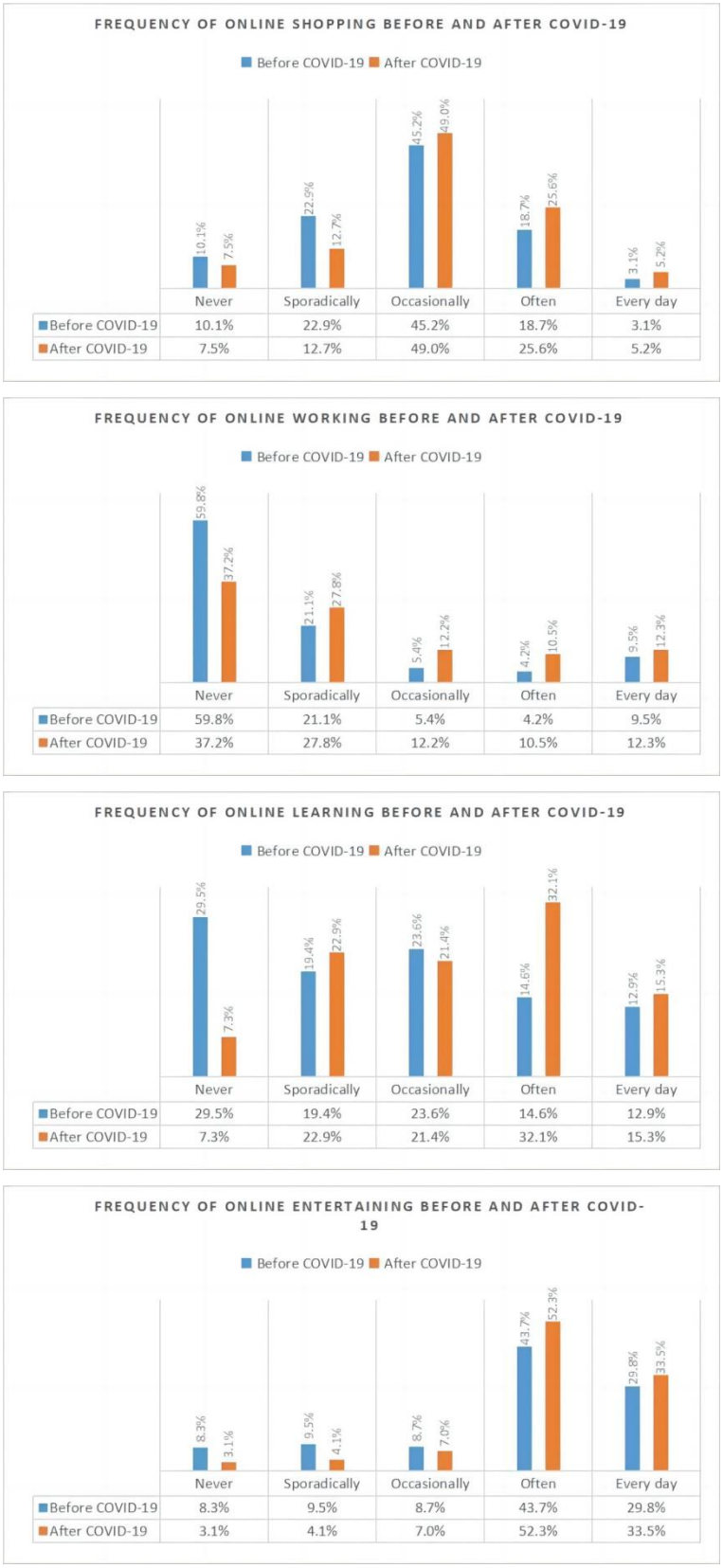

Figure 3. Frequency of online activities before and after COVID-19 in Wuhan.

4.2 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.4). 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.

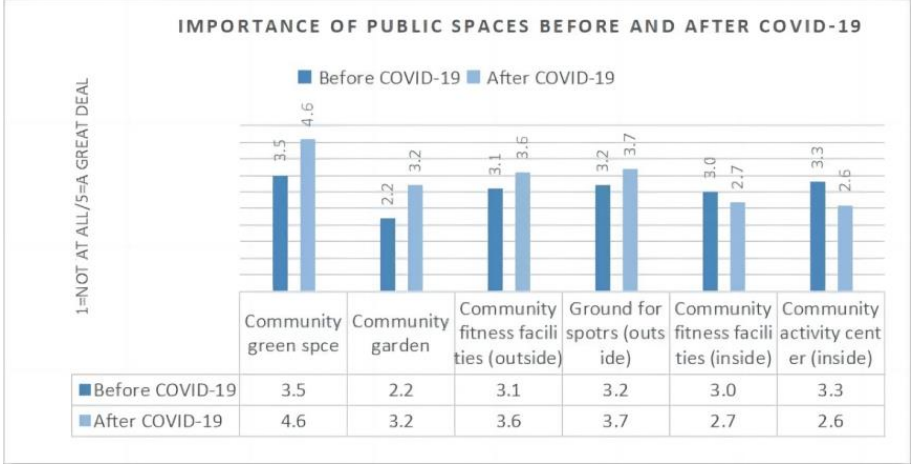

Figure 4. Mean values of importance of spaces before and after COVID-19.

Moreover, I detected that people's daily travel range narrowed down considerably. In Figure 5, 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.

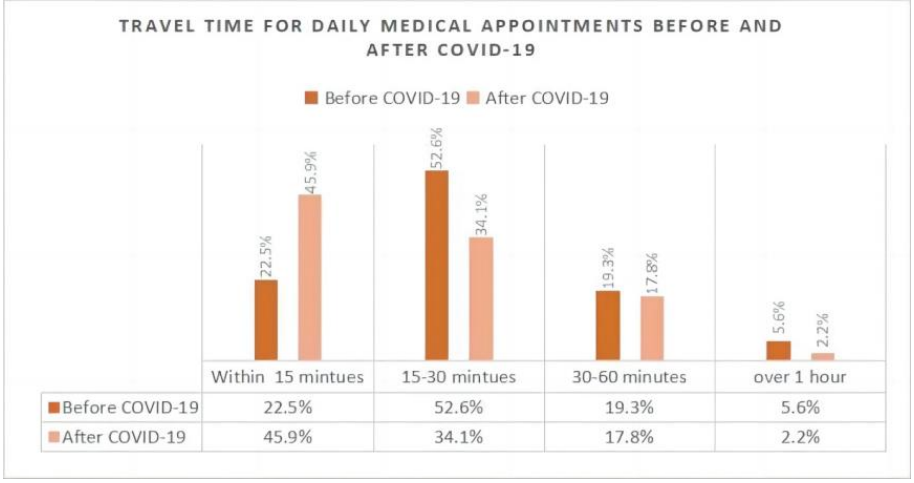

Figure 5. Travel time for medical appointments before and after COVID-19.

4.3 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.6). 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 6. 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		
Roof	Addition of terrace or roof layer	1/3	2021.3	Owners	2	S	Physical and mental health benefits	Self-sufficiency in extreme circumstances Multiple and adaptive uses
	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		

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.

3.1 From the results of keyword co-occurrence analysis by CiteSpace (see in Figure.7), 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.

3.2 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.

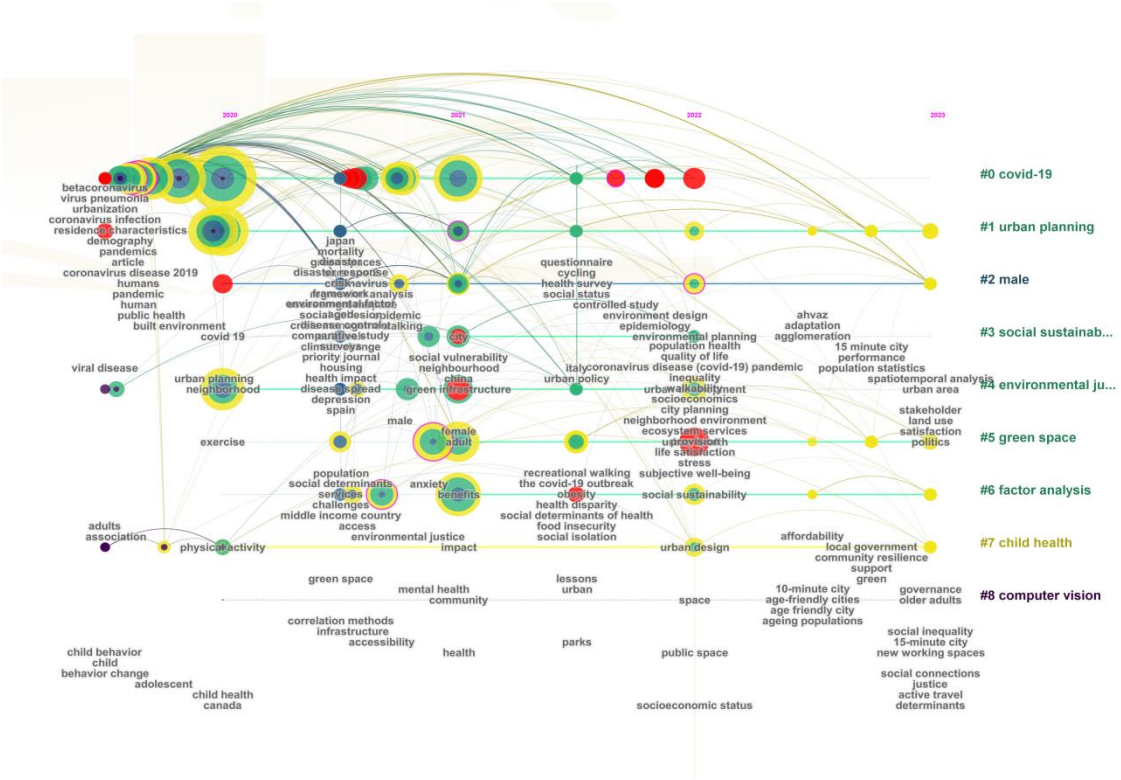

Figure 7. Co-occurring keywords timeline from 2020 to 2023 in CiteSpace

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.8).

Figure.8 Urban district of Wuhan, China

3.3 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 M_D among assessment indicators. Next, I standardized the initial direct impact matrix M_D to obtain the comprehensive impact matrix M_T. 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

3.4 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.9.

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.

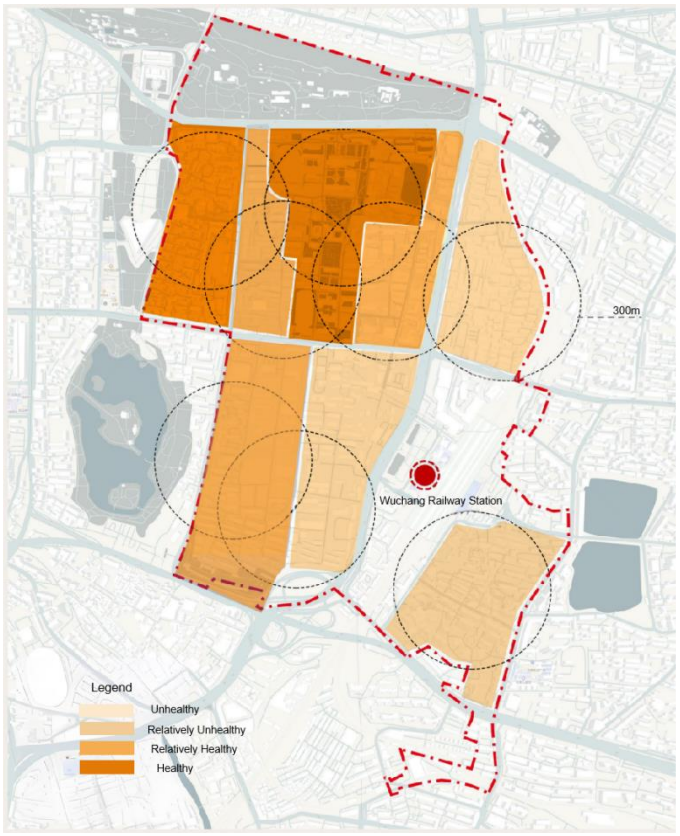

Figure 9. Results of the health rating in targeted districts

5. List of publications

[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. https://doi.org/10.3390/SU15129770

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