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Planning cities for pandemics: review of urban and transport planning lessons from COVID-19

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For the past few years, the world has been facing one of the worst pandemics of modern times. The COVID-19 outbreak joined a long list of infectious diseases that turned pandemic, and it will most likely leave scars and change how humans live, plan and manage urban space and its infrastructures. Many fields of science were called into action to mitigate the impacts of this pandemic, including spatial and transport planning. Given the large number of papers recently published in these research areas, it is time to carry out an overview of the knowledge produced, and synthesising, systematising and critically analysing it. This paper aims to review how the urban layout, accessibility and mobility influence the spread of a virus in an urban environment and what solutions exist or have been proposed to create a more effective and less intrusive response to pandemics. This review is split into two avenues of research: spatial planning and transport planning, including the direct and indirect impact on the environment and sustainability.

Keywords: COVID-19/town & city planning/transport planning/UN SDG 3: Good health and well-being/UN SDG 11: Sustainable cities and communities

1. Introduction

On the last day of 2019, with the new year's celebrations underway, a cluster of pneumonia cases of unknown causes were reported from Wuhan, Hubei province, China (WHO, 2020). From that moment, societies worldwide faced one of the worst pandemics of modern times. From all over the world and across different areas of knowledge, researchers started looking for solutions to reduce the spread of the contagion while trying to adapt an unaware and unprepared society to a global pandemic. Urban areas became the centre of most outbreaks during these 2 years (Acuto, 2020): with over half of the world's population living in urban areas, most of which easily connect among each other and with each other (UN, 2018), cities became the main areas of concern for the rapid spread of the virus. This pandemic has impacted, arguably forever, cities, as other pandemics did in the past (Eltarabily and Elgheznawy, 2020). As spatial and transport planning certainly influences the spread of a virus in urban environments, in the future, they must become part of short- and long-term solutions to other outbreaks of infectious diseases.

The novel coronavirus disease (COVID-19) first caught the attention of urban and transport planners when a lockdown was declared in Wuhan on 23 January 2020. Words such as 'social distancing' and 'self-isolation' started echoing worldwide at a stage where urban and transport planning was heading in a different, almost opposite direction: cities were becoming denser and more compact, and transport planning policies were aiming for higher public transport mobility and overall mass use. Inevitably, this led to COVID-19 making an enormous impact on cities, as recognised by Krishna and Kummitha (2020). Cities thus face the daunting tasks of mitigating COVID-19 impacts, and spatial and transport planning are becoming frontrunners in this quest, as argued by Ibert *et al*. (2022) and Tešić and Lukić (2020).

This paper aims to review the state-of-the-art research produced in spatial and transport planning concerning COVID-19, from its inception to the present, to summarise and analyse the main conclusions and to suggest new avenues of research on the relationships between the urban layout, accessibility, mobility and the spread of a virus in an urban environment. The motivation for this review was to systematise the knowledge in the field, contributing by creating a coherent overview of the research landscape, filling a literature gap on reviews of COVID-19 impacts on municipal engineering. Furthermore, it suggests lines of future research that, as will be observed, address pandemics and also connect that aspect with other essential aspects of the urban environment, society and sustainability. Sections 2 and 3 highlight the core role that both spatial and transport planning have during pandemic times and how COVID-19 might redirect research and change policies and practice in the short and long terms.

2. Spatial planning and COVID-19

Acuto (2020) and Ahsan (2020) have shown that spatial planning can have an essential role in the fight against COVID-19 and future pandemics by adapting to the new circumstances both in the short- and long terms. This section takes a closer look at how the theory and practice of spatial planning evolved due to COVID-19 and previous pandemics, highlighting the importance of green areas and parks in urban areas, how bigger cities have bigger problems and the disparities between developed and developing countries.

2.1 What has the past taught us; what does the future hold?

History has taught us about past pandemics, their origins, spread and consequences. COVID-19 did not open a new area of research in this respect, but instead reopened one that had been dormant for many decades. Hays (2005) provides an overview of 50 epidemics and pandemics that humans faced, from the epidemic in Athens in 430–427 BC to contemporary malaria and tuberculosis outbreaks. Looking at the timeline of all major pandemics, a worrisome statistic arises: from 430 BC to 2005, a total of 50 pandemics were recorded, whereas from 2005 to 2020, a total of six pandemics made worldwide news, a 25-fold increase in the frequency of pandemics. With the world population climbing, societies evolving and claiming previously uninhabited natural zones, the appearance and spread of new viruses have a higher potential for dire consequences, increasing the need for pre-emptive planning and prompt responses.

Pandemics have already led to changes in how the urban environment is planned and managed (Brinkley, 2020; Füller, 2016; Martínez and Short, 2021; Nanisetti, 2020). For example, when New York, Paris and London had cholera outbreaks, inhabitants searched for open green and sunny areas, which led to the creation and design of buildings and outdoor areas to provide fresher air and sunlight (Antunes, 2021; Klein, 2020). The Garden City Movement is an example of urban planning acting as a tool to fight, among others, poor living conditions, lack of sanitation and the Spanish flu of the twentieth century (Allam and Jones, 2020; Lai *et al.*, 2020). In fact, several authors encouraged architectural and urban organisations to start including pandemics in disaster management strategies, with integrated containment measures in a seamless way, within the typical city environment (Allam and Jones, 2020; Paital, 2020; Salama, 2020). Bouffanais and Lim (2020) urged urban analysts and planners to understand the dynamics of city movement, as urban flows may help explain the spread of COVID-19 within the built environment. Martínez and Short (2021) suggested that urban spaces should be rethought and planned for safer and more sustainable cities, starting with parks and green areas in densely populated conurbations.

2.2 Green areas as physical and mental safety nets

The COVID-19 pandemic has imposed the necessity to stay home to extremely connected and mobility-based societies. Life in confinement was something that most people were not used to, which led to an increase in the number of people suffering from mental health issues (Amit *et al.*, 2021). Psychological health factors that added to economic and social insecurities took an even bigger toll on people's lives (Mazza *et al.*, 2020), with children suffering the most from forced confinement (Tomikawa *et al.*, 2021).

The claustrophobic nature of many residences in urban environments resulted in an increased use of urban parks and green areas during lockdowns (Venter *et al.*, 2021). Urban parks and green areas have proven to be essential to the well-being of residents, creating higher resiliency and overall quality of life for their nearby population (Cheng *et al.*, 2021; Slater *et al.*, 2020; Xie *et al.*, 2020). In addition, travel patterns emerged that indicated people opt for parks close to their homes with a travel time under 10 min, reinforcing the importance of neighbourhood parks and green areas (Ugolini *et al.*, 2020; Xie *et al.*, 2020). These authors suggested creating networks of small decentralised parks and green areas accessible for everyone, allowing for easier interactions with nature and providing a place with clear mental and physical benefits. Private gardens were also proven to be important for residents, emphasising the importance of both public and private gardens for improved resiliency (Marques *et al.*, 2021; Poortinga *et al.*, 2021).

2.3 Big cities, big problems

Internationally connected cities – that is, cities that host international hubs, industry and companies – were typically more affected in comparison with smaller urban areas and rural zones. Because big cities directly correlate with international

cities, large urban areas and metropolises became the main clusters for the spread of COVID-19 (Ahsan, 2020). Wuhan, Shanghai, Hong Kong, London, Milan, Madrid, Barcelona, New York and São Paulo, among many other cities worldwide, had the largest COVID-19 outbreaks. Even when infections appear in satellite cities or metropolitan areas, the outbreak tends to move towards the city, as was the case in Milan or Oporto.

The idea that population density and urban areas help the spread of COVID-19 has been a possibility ever since the appearance of the virus (Desai, 2020; Liu, 2020). Salama (2020) compared the spread of the previous severe acute respiratory syndrome outbreak in 2003 and the current outbreak, underlining a positive correlation between higher density and rapid spread, which Peng *et al.* (2020) confirmed. Higher densities can relate to low per-capita income, space overcrowding and poor access to healthcare, originating more outbreaks among poorly housed communities (Lai *et al.*, 2020). Higher-density neighbourhoods are also related to lower well-being during the pandemic, in comparison with lower-density neighbourhoods; lower-income neighbourhoods and areas of minority concentration with smaller dwellings, less green space and higher reliance on public transport were negatively associated with well-being (Carrión *et al.*, 2021; Hatef *et al.*, 2020; Hong *et al.*, 2020; Mouratidis, 2022). In contrast, good accessibility to local facilities and better access to amenities and public health infrastructure have been positively associated with well-being and reduced vulnerabilities in high-density areas (Mouratidis, 2022; Mouratidis and Yiannakou, 2022; Sharifi and Khavarian-Garmsir, 2020). Lower density resulted in lower infection and death rates, as claimed by Hamidi *et al.* (2020) and Carozzi *et al.* (2020). The incongruity of compact planning transpires once more, suggesting it continuously needs to be addressed and improved, mainly in urban areas where informal settlements are home for most of the residents.

2.4 Slums: a COVID-19 playground?

Already known for poor living conditions, slums – that is, dense informal settlements, might be the least prepared urbanised areas to fight this pandemic, with a lack of basic infrastructure such as sewers, waste collection, drainage or even clean drinking water (Corburn *et al.*, 2020; Patel, 2020). Slums have an already bad situation that has worsened considerably with the onset of the pandemic (Chigbu and Onyebueke, 2020). Obongha and Ukam (2020) analysed different settlement patterns in Nigerian cities, places of serious concern for epidemiologists, virologists and planners. Due to a lack of urban planning policies, buildings are extremely close to each other, making it nearly impossible to have any social distancing. Bearing in mind the lack of space, overcrowding and imminent violence, social distancing and hygienic measures are impractical, leaving millions of people with even less protection from the rapid spread of COVID-19 (Cheshmehzangi, 2021; Corburn *et al.*, 2020; Martínez and Short, 2021; Patel, 2020).

Slums are neither a problem caused solely by mismanaged urban planning, and nor are they solvable by urban intervention alone (Bolay, 2006). Its residents are economically vulnerable, and COVID-19 worsened that vulnerability, as Patel (2020) argued when looking at slums in Indian cities. Patel also argued that smart cities' solutions to better control the spread of the COVID-19 virus and one-size-fits-all measures will not work for slums. Instead, Patel suggests that providing long-term solutions to reduce the vulnerability of marginalised populations is a prerequisite to making cities more resilient.

3. Transport planning and COVID-19

The COVID-19 pandemic had a massive impact on transport patterns, mostly due to the closing of international borders and country-scale lockdowns. Zhang and Zhang (2021) and Valenzuela-Levi *et al.* (2021) argued that some behavioural pattern changes might be long term or even permanent. Analysing city mobility alterations during a lockdown is the first step to understand how transport planning adapted to this new, unforeseen paradigm. Because cities host mobile populations, transport services and foster social interactions, their intercity and intracity public transport systems increase a city's vulnerability to the spread of contiguous diseases (Carozzi *et al.*, 2020; Lak *et al.*, 2020), both at the hub locations (stations) and inside the transport vehicles, making it important to analyse the role of public transport amidst the pandemic. By contrast, active mobility has a small associated risk of contagion, which contributed to the reinforcement of its position on the urban transport agenda. Additionally, ripple effects in air pollution emerged, due to changes in mobility patterns, which must be mentioned.

3.1 Mobility during lockdown

With the number of cases on the rise, cities worldwide underwent lockdown measures, enforced either by local or nationwide government decisions (Gargoum and Gargoum, 2021). With severe restrictions, urban transport significantly reduced. Several studies analysed the impact that the pandemic had on mobility, with public transport suffering from a drastic decrease in ridership, due to people preferring to use private transport, both motorised and non-motorised, for a reduced chance of contagion (Aloi *et al.*, 2020; Badii *et al.*, 2020; Eisenmann *et al.*, 2021; Scorrano and Danielis, 2021). Nevertheless, people still needed to move, either to work, restock food or for services, so not all trips could be curtailed (Borkowski *et al.*, 2021).

Parr *et al*. (2020) showed that by 22 March 2020, during the state-wide lockdown in Florida, traffic volumes dropped to an average of 47.5% in comparison with the homologous value in 2019, with urban areas all around the state exhibiting an earlier and more significant decline in traffic volumes in comparison with rural areas. Osservatorio Audimob (2020) analysed the impact of the COVID-19 lockdown on general trips in Italy, having found that during the worst pandemic stage, all-purpose countrywide mobility declined from an average of 85% in 2019 to just 32%. Parr *et al*. also concluded that proximity mobility – that is, walking trips taking <5 min, rose from 6 to 17%, while commuting and leisure trips dropped from 91 to 49%. Fatmi (2020) found similar figures, with out-of-home activities in the Kelowna region of British Columbia, Canada, dropping over 50% during the COVID-19 pandemic. Aloi *et al*. (2020) presented a detailed analysis for Santander, Spain. Overall results show that mobility plunged by over 76%, with the private car being the least affected and public transport being the most affected, with a staggering 93% reduction. A noteworthy by-product was the reduction of up to 67% of traffic accidents. That study also revealed an interesting change in modal share between pre- and post-pandemic times, with a rise from 48 to 77% of the private car and a reduction of 7.8 to 2.3% of public transport trips. Commuting trips became the main reason for people to leave their homes, rising from 35 to 74% during the pandemic.

The pandemic also impacted commuters and the future of commuting. Singh *et al*. (2020) found a significant impact on how people view and perceive safety when travelling, with metro, carpool and buses observing a decline in modal share, whereas walking and the private car rose their share. Choosing a mode of transport was mostly based on travel time, cost and overall convenience, and the inconvenience of wearing masks or social distancing also became valid arguments (Sameni *et al*., 2021). Rubin *et al*. (2020) conducted an international online survey among individuals who regularly commuted to their workplace and concluded that 69% of the respondents miss at least some aspects of commuting, such as the commuting itself (53%), spending some time on their own (25%) or feeling independent (24%). People do not all miss commuting equally: those who frequently commute by private cars are the least affected, with over 50% not missing commuting at all. As for public transport users, 75% did not miss commuting. Active transport users – for example, (e-)cyclists and pedestrians – are the ones who missed commuting the most comprising 91%. Another interesting conclusion of Rubin *et al*. (2020) was that the more time a person had to spend commuting, the less that person would miss it.

Perhaps the most important question concerning the reduction in travelling and lockdowns is whether it impacted the spread of COVID-19. According to Gargoum and Gargoum (2021), it did: countries that were faster to respond had significantly lower mortality rates per 100 000 people and managed to implement less strict lockdown strategies. Furthermore, the study highlighted that there is a potential positive correlation between (*a*) taking early action and lower mortality rates; (*b*) taking early actions and being able to maintain a higher level of mobility and (*c*) taking early action and the potential of observing an early recovery onset, thus setting a benchmark on disaster relief actions.

3.2 COVID-19 and mobility patterns

The hypermobile society enhanced the virulence of the contagion (Musselwhite *et al*., 2020). The virus quickly entered big international cities, rapidly spreading to the rest of the country, helped by the fact that people infected with COVID-19 become contagious before showing any symptoms or even being completely asymptomatic (Javid *et al*., 2020). A study by Badr *et al*. (2020), based on daily mobility data from mobile phones, has shown a strong correlation between mobility patterns and COVID-19 cases, with the lockdown resulting in lower mobility and consequently a decrease in the growth of COVID-19 cases for those same areas. Additionally, changes in mobility patterns were only perceptible after 9–12 days of COVID-19 transmission, consistent with the incubation time of the virus (Badr *et al*., 2020). Similarly, Cartenì *et al*. (2020) conducted a quantitative estimation through a multiple regression model to prove a connection between mobility and overall trips made within Italy and new COVID-19-positive cases.

3.3 Environmental flip side of standing still

High levels of air pollution in cities are a serious environmental issue that most cities worldwide have been facing over the past few decades (Mayer, 1999). Several authors have found a positive correlation between air pollution levels and COVID-19 incidence and severity (Espejo *et al*., 2020; Sasidharan *et al*., 2020; Setti *et al*., 2020). The positive correlation between urban transport and air pollution is also well documented (Kumar *et al*., 2015; Shabbir and Ahmad, 2010), and indeed a reduction in travelling from lockdowns had a direct impact on pollution and air quality, despite the increase in the private car modal share. Lockdowns were, in fact, the first time in modern history where societies radically reduced global greenhouse emissions and improved both air and water quality (Abdullah *et al*., 2020; Baldasano, 2020; Dantas *et al*., 2020; Gama *et al*., 2020; Krecl *et al*., 2020; Lian *et al*., 2020; Mahato *et al*., 2020; Nakada and Urban, 2020; Sharifi and Khavarian-Garmsir, 2020; Sharma *et al*., 2020; Xu *et al*., 2020). With most of the cities in the world on lockdown, according to data from National Aeronautics and Space Administration and European Space Agency, pollution lowered by up to 30% in COVID-19 epicentres such as Italy, Spain, Wuhan or the USA (Muhammad *et al*., 2020). It is

however unclear whether this new evidence can change the willingness and capability of worldwide governments to promote policies and changes in transport planning to improve air quality and overall sustainability (Cadotte, 2020; Sharma *et al*., 2020).

3.4 Public transport mid a pandemic

Several researchers agreed that public transport, as it was before COVID-19, was a prime space for person-to-person transmission (Gutiérrez *et al*., 2020; Meyer and Elrahman, 2019; Musselwhite *et al*., 2020; Teixeira and Lopes, 2020). Commuters are confined in small and limited spaces, which are more prone to virus transmission (WHO, 2020). If there is active contagion on public transport, it is impossible to identify the passengers who might have been in proximity to the person infected (Musselwhite *et al*., 2020). Both public transport vehicles and stations have multiple surfaces that are constantly used by several people: leaving seats, handrails, doors and ticket machines prone to easy virus transfer surfaces (Tirachini and Cats, 2020). Due to this, public transport was the most affected of all modes, both in terms of ridership and rider trust. Indeed, ridership plummeted all over the world, with examples such as Switzerland (90% decrease), Sweden (40–60% across regions), Curitiba, Brazil (80% decrease) or Santiago, Chile (reduction in subway trips of 55% and 45% in bus trips) (Astroza *et al*., 2020; Fumagalli *et al*., 2021; Hörcher *et al*., 2022; Jenelius and Cebecauer, 2020; Molloy *et al*., 2020; Thombre and Agarwal, 2021; Tirachini and Cats, 2020).

COVID-19 temporarily brought to a halt the ongoing endeavours by municipal authorities to promote and raise public transport ridership, creating new challenges for both authorities and commuters (Gutiérrez *et al*., 2020). Fear on the commuter side might take over, making it plausible that public transport is traded for other means of transport, as some reports have evidenced (Przybylowski *et al*., 2021; Thomas *et al*., 2021; Waka Kotahi, 2020). In fact, Thombre and Agarwal (2021) and Das *et al*. (2021) found an increase in car dependency, with people willing to shift towards the private car. Such a shift is, however, not desired; as Dong *et al*. (2021) state, in a health crisis, public transport should protect passengers while still meeting travelling demand, improving their operational modes by increasing service frequency and ensuring physical distance among passengers. At this stage, it is still uncertain what the ramifications and long-term impacts of the pandemic truly are for public transport. However, the fostering of higher ridership levels has become more problematic.

3.5 Walking and cycling: towards a post-COVID-19 future?

As lockdowns were enforced, walking and cycling were observed by many as resilient and reliable modes of transport with a small risk of contagion. Cities observing this phenomenon started promoting cycling by creating new and additional bike lanes, reducing the prices of bike-sharing systems, restricting car circulation and creating incentives for bicycle purchases (Barbarossa, 2020; Büchel *et al*., 2022; Kraus and Koch, 2021). Zhang and Zhang (2021) argued that the disruptions in spatial and transport planning might make it the right time for active mobility to seize the opportunity and gain even more momentum. This trend was also supported by recent research relating COVID-19 and active transport, which advocated for greater support and implementation of active transport solutions (Büchel *et al*., 2022; De Vos, 2020; Lak *et al*., 2020; Laverty *et al*., 2020; Musselwhite *et al*., 2020; Rubin *et al*., 2020; Singh *et al*., 2020). On the field, local and international entities are prompting green solutions aiming for the decline in car-based transport infrastructure in exchange for adequate cycling infrastructure (Cheshmehzangi, 2021).

Research by Teixeira *et al*. (2021) has shown that despite decreasing ridership, bicycle-sharing systems have higher resiliency in comparison with public transport, and compelling evidence surfaced of a modal shift from public transport to bicycle ridership (Nikiforiadis *et al*., 2020; Teixeira and Lopes, 2020) and active mobility in general (Harrington and Hadjiconstantinou, 2022; Lock, 2020). This is a positive sign for low- and middle-income countries, where public transport is often overloaded. Higher shares of walking and cycling can be beneficial by reducing public transport pressure (Koehl, 2020).

More and more cities are including active mobility in their agendas, and this pandemic brought an opportunity for higher commitment alongside new and improved solutions. Cities in Italy, such as Turin, Naples, Milan, Bari and Palermo, are actively working on post-COVID mobility solutions (Barbarossa, 2020). England and France also recognised the opportunity and created investment packages for a new era of cycling (Brooks *et al*., 2020; Buehler and Pucher, 2021). Findings by Thombre and Agarwal (2021) indicate that building new infrastructure can increase bicycle share from 31% to approximately 44% in India. Openness to new transport policies in favour of new car restrictions, more pedestrian space and a switch to more sustainable mobility gained more acceptance during the pandemic compared with normal circumstances (Awad-Núñez *et al*., 2021). The lockdown period drove a collective reflection on sustainability, which on its own, provides an important window of opportunities for change (Awad-Núñez *et al*., 2021; Dhillon, 2020; Goetsch and Quiros, 2020; Huet, 2020; Ro, 2020; Shaer *et al*., 2021; Sharifi and Khavarian-Garmsir, 2020; Sui and Prapavessis, 2020; Wood, 2020), and more attention to the promotion and implementation of active transport mobility (Budd and Ison, 2020; Nelson, 2020). It is now

imperative to develop temporary and permanent new policies (Buehler and Pucher, 2021; Cheshmehzangi, 2021), which, if successful, might generate between $1 and $7 billion in health benefits annually (Kraus and Koch, 2021). A study by Buehler and Pucher (2022) analysed and compared bicycle levels between 2019 and 2021 from 14 different cities and concluded that cycling levels generally increased from 2019 to 2021, mostly due to recreational and exercise trips, whereas cycling trips to work and education declined.

To achieve higher levels of sustainability in a post-COVID-19 era, urban transport policies must aim for higher resiliency, social equity and reduce the carbon dioxide emissions (Valenzuela-Levi *et al*., 2021). The authors show that some of these objectives may be achieved by combining adequate housing location and cycling promotion in an integrated policy. This suggestion was corroborated in recent research, which used quantitative arguments to argue that planned urbanism is a possible path to achieve equity and reduce the carbon dioxide emissions (Monteiro *et al*., 2022).

Table 1. Conclusions and research opportunities

Conclusion	Research opportunities
C1. Disaster management plans for urban environments should include provisions for pandemic health crises.	R1. Design efficient and seamless lockdown areas based on spatial and transport planning procedures to prevent mass contagion.
C2. Large and dense built environments propitiate disease contagion.	R2. Deepening the link between contagion and compact development/high density living.
C3. Proximity-based parks and green areas mitigate lockdown effects.	R3. Development of methodologies that combine active accessibility to parks and green areas with contagion risk when those areas are small.
C4. The different and harsh reality of informal settlements does not fit in the typical solution for developed countries urban areas.	R4. Develop specific solutions for contagion mitigation in informal settlements. Monitor the efficacy of the solutions in the field.
C5. Lockdown-induced traffic reduction directly led to a reduction of air pollution and air quality improvement. A world-scale impact that would otherwise not be experienced.	R5. Use of data collected during lockdown for transport planning, mobility and air quality analyses.
C6. COVID-19 added a health safety dimension to the choice of transport mode.	R6. Scrutinise the impact that this new perception has on commuters.
C7. Public transport experiences ridership losses during pandemics due to fear of contagion. The task of promoting and improving public transport became harder.	R7. Investigate effects of social distancing and respiratory etiquette on contagion within public transport. Issue recommendations to transport authorities.
C8. Active mobility, e.g. walking and cycling have proven to be safe and resilient modes of transport in urban areas.	R8. Use active accessibility studies to optimise the deployment of urban facilities. Work together with municipal authorities to design and implement cycling and pedestrian network infrastructure.

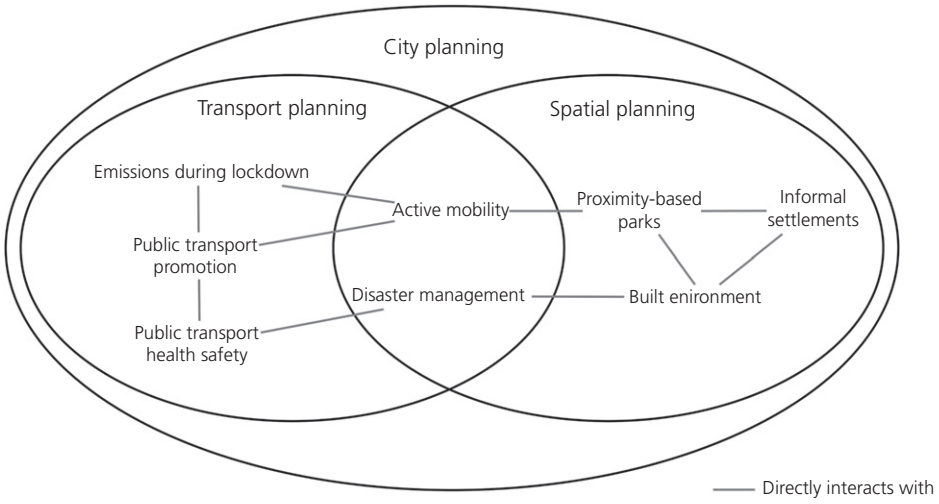

Figure 1. Framework of the findings

4. Conclusions and future research

Cities face new and daunting challenges in the post-COVID-19 era, with spatial and transport planning in the spotlight of a society that needs and must change (Ibert *et al*., 2022; Tešić and Lukić, 2020). Difficult and unusual decisions had to be taken during the pandemic, with limited knowledge by those taking them. Two years of dealing with the pandemic has resulted in publication of numerous papers concerning COVID-19 and pandemics in general, including those dealing with urban and transport planning issues. This review showed that the consequences of pandemics are now better understood at that level, and clear city planning implications begin to emerge. It was also observed that research at the beginning of the pandemic was mostly theoretical since little to no field data were available and that current research is starting to take a more practical approach. Concomitantly, new avenues of research have been opened for both academics and practitioners. Table 1 summarises the main findings of this review and suggests directions for future research concerning planning cities for pandemics. Figure 1 presents a visual framework for the findings, noting that the suggested links should be taken with a grain of salt since in an urban environment everything is interconnected; the links show only what are arguably the strongest relationships. An extensive description of the multiple aspects found in COVID-19 research papers related to spatial and transport planning is presented in Appendix Table 2.

Researchers are aware that there would be more pandemics in the future, however, societies need to be prepared. As Rojas-Rueda and Morales-Zamora (2021) also concluded in their literature review:

> COVID-19 offers an opportunity to rethink the built environment and transport infrastructure with the aim to support short-term mitigation strategies and reduce long-term urban health inequities.

Research may look in a holistic manner at the future of society, cities, mobility and high interconnectivity, learning from this pandemic the mistakes and the right calls. If done properly, spatial and transport planning can mitigate mass disease dissemination, possibly even helping epidemiologists trace high-risk contacts while simultaneously catering for other urban and societal needs in the perpetual quest of achieving higher resiliency and sustainability for all.

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Appendix

Table 2

Table 2. COVID-19-related research papers in spatial and transport planning

		Spatial planning									Transport planning					
	Location	COVID-19 timeline	Past pandemics, their impacts and timeline	COVID-19 impact on urban areas	COVID-19 consequences on mental health and safety perception	General urban planning considerations	Lessons learned from the COVID-19 pandemic	Urban planning as a tool to fight the COVID-19 and future pandemics	Green areas as physical and mental safety nets during COVID-19 lockdown	Impact of density, compactness and world connection on the spread of COVID-19	General urban transport considerations	Travel patterns under COVID-19 lockdown	Role of accessibility and proximity	Public transport and COVID-19	Active mobility and COVID-19	COVID-19 and the environment flip side
Abdullah *et al*. (2020)	Malaysia															X
Acuto (2020)	Global	X						X								
Ahsan (2020)	Turkey							X		X						
Allam and Jones (2020)	Global		X				X	X								
Aloi *et al*. (2020)	Santander										X	X				
Amit *et al*. (2021)	Bangladesh				X											
Antunes (2021)	Global							X	X							
Astroza *et al*. (2020)	Chile											X		X		
Awad-Núñez *et al*. (2021)	Spain					X					X				X	
Badii *et al*. (2020)	Florence											X				
Badr *et al*. (2020)	USA	X										X				
Baldasano (2020)	Barcelona/Madrid															X
Barbarossa (2020)	Italy			X											X	
Bolay (2006)	Slums					X										
Borkowski *et al*. (2021)	Poland										X	X				
Brinkley (2020)	Singapore		X				X									
Brooks *et al*. (2020)	USA										X				X	
Büchel *et al*. (2022)	UK														X	
Budd and Ison (2020)	Basel/Zurich					X					X				X	
Buehler and Pucher (2021)	Global										X				X	
Buehler and Pucher (2022)	Europe/USA		X	X							X	X			X	
Carozzi *et al*. (2020)	USA										X		X			
Carrión *et al*. (2021)	New York City									X						
Carteni *et al*. (2020)	Italy	X		X								X				
Cheng *et al*. (2021)	Nanjing City						X		X							
Cheshmehzangi (2021)	Global									X					X	X
Corburn *et al*. (2020)	Slums									X						
Dantas *et al*. (2020)	Rio de Janeiro															X
De Vos (2020)	Global										X				X	
Desai (2020)	Global									X						
Dhillon (2020)	India					X					X					
Dong *et al*. (2021)	China													X		
Eisenmann *et al*. (2021)	Germany											X		X		
Eltarabily and Elgheznawy (2020)	Global		X				X									
Espejo *et al*. (2020)	Global															X
Fatmi (2020)	British Columbia											X				
Füller (2016)	Hong Kong		X													
Fumagalli *et al*. (2021)	Curitiba												X		X	
Gama *et al*. (2020)	Portugal															X

Gargoum and Gargoum (2021)	Global	X		X							X	X				
Goetsch and Quiros (2020)	Global					X					X					
Gutiérrez *et al.* (2020)	Global														X	
Hamidi *et al.* (2020)	USA									X						
Harrington and Hadjiconstantinou (2022)	UK														X	
Hatef *et al.* (2020)	USA									X						
Hays (2005)	New York		X													
Hong *et al.* (2020)	Global									X						
Hörcher *et al.* (2022)	Global											X		X		
Huet (2020)	Europe					X					X					
Ibert *et al.* (2022)	Global			X			X									
Javid *et al.* (2020)	Global	X		X												
Jenelius and Cebecauer (2020)	Sweden											X		X		
Klein (2020)	New York								X							
Koehl (2020)	Global													X	X	
Kraus and Koch (2021)	Europe														X	
Krecl *et al.* (2020)	São Paulo															X
Krishna and Kummitha (2020)	Global			X												
Kumar *et al.* (2015)	Global										X					
Lai *et al.* (2020)	Global		X							X						
Lak *et al.* (2020)	Global										X				X	
Laverty *et al.* (2020)	UK										X				X	
Lian *et al.* (2020)	Global															X
Lock (2020)	Australia														X	
Liu (2020)	China									X						
Mahato *et al.* (2020)	India															X
Marques *et al.* (2021)	Rio de Janeiro				X		X		X							
Martínez and Short (2021)	Global		X	X						X						
Mayer (1999)	Global					X										
Mazza *et al.* (2020)	Italy				X											
Meyer and Elrahman (2019)	Global														X	
Molloy *et al.* (2020)	Switzerland											X		X		
Mouratidis and Yiannakou (2022)	Greece												X			
Mouratidis (2022)	Norway									X			X			
Muhammad *et al.* (2020)	Global															X
Musselwhite *et al.* (2020)	Global	X		X						X					X	
Nakada and Urban (2020)	São Paulo															X
Nanisetti (2020)	India		X													
Nelson (2020)	Global					X					X				X	
Nikiforiadis *et al.* (2020)	Thessaloniki														X	
Obongha and Ukam (2020)	Nigeria									X						
Osservatorio Audimob (2020)	Italy											X				
Paital (2020)	Global							X								
Parr *et al.* (2020)	Global											X				
Patel (2020)	India									X						
Peng *et al.* (2020)	Wuhan									X						
Poortinga *et al.* (2021)	UK						X		X							
Przybylowski *et al.* (2021)	Gdansk													X		
Ro (2020)	Global					X					X					
Rojas-Rueda and Morales-Zamora (2021)	Global			X		X	X	X			X					X
Rubin *et al.* (2020)	Global				X							X			X	
Salama (2020)	Global						X	X		X						
Sameni *et al.* (2021)	Global South				X									X		
Sasidharan *et al.* (2020)	London															X
Scorrano and Danielis (2021)	Trieste											X			X	
Setti *et al.* (2020)	Bergamo															X
Shabbir and Ahmad (2010)	Pakistan										X					
Shaer *et al.* (2021)	Shiraz					X					X					
Sharifi and Khavarian-Garmsir (2020)	India												X			X
Sharma *et al.* (2020)	Global										X					X
Singh *et al.* (2020)	Global				X						X	X		X	X	
Slater *et al.* (2020)	Global						X	X	X							
Sui and Prapavessis (2020)	Canada					X					X					

Teixeira and Lopes (2020)	New York																							
Teixeira *et al.* (2021)	Lisbon																							
Tešić and Lukić (2020)	Global																							
Thomas *et al.* (2021)	New Zealand																							
Thombre and Agarwal (2021)	India																							
Tirachini and Cats (2020)	Global																							
Tomikawa *et al.* (2021)	Tokyo																							
Ugolini *et al.* (2020)	Europe																							
UN (2018)	Global																							
Valenzuela-Levi *et al.* (2021)	Santiago Chile																							
Venter *et al.* (2021)	Norway																							
Waka Kotahi (2020)	New Zealand																							
WHO (2020)	Global	X																						
Wood (2020)	Global			X																				
Xie *et al.* (2020)	Chengdu																							
Xu *et al.* (2020)	China																							
Zhang and Zhang (2021)	Global																							
Total	—	7	9	12	8	14	13	10	8	17	25	26	4	17	25	17

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