19. Human Mobility in the Postpandemic World

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19.1 INTRODUCTION

The COVID-19 pandemic has undeniably reshaped urban life across the globe, particularly in how people move within and between urban spaces (de Palma, Vosough, and Liao 2022; Kopecka-Piech and Łódzki 2022; Loa et al. 2021). The disruption caused by the pandemic provided an unprecedented challenge for policymakers to revisit and innovate transportation and planning strategies. These changes affect everything from daily commutes to international travel (Huang et al. 2022a; Ren et al. 2022). As cities begin to recover from the impacts of the pandemic, it is crucial to examine these transformations to understand the future of urban mobility (Qiang and McKenzie 2024).

Cities are complex systems made by various processes and elements (Batty 2005; Yuan and Raubal 2016). The behavior of individuals, who serve as the basic elements in an urban system, can be broadly abstracted into the spatial and temporal characteristics of that system (Ahas et al. 2010; Yuan, Raubal, and Liu 2012). Therefore, individual mobility influences economic dynamics, social interactions, and access to services and opportunities (Li and Liu 2019; Xu et al. 2021). The importance of studying urban mobility in a postpandemic world cannot be overstated. The changes witnessed during the pandemic have highlighted the vulnerabilities and strengths of existing transport systems (Loa et al. 2021; Qiang and McKenzie 2024). For example, social distancing measures led to a drastic decrease in the use of public transport, whereas the fear of contagion drove an increase in alternative modes of transport such as biking and walking (De Vos 2020). These shifts have prompted cities to rethink their urban spaces and reevaluate existing infrastructure.

Moreover, the pandemic has underscored the inequalities in urban mobility that affect different demographic groups in various ways (Chow et al. 2020; Huang et al. 2022b). Low-income communities often faced the dual challenge of greater exposure to the virus due to dependency on public transport and greater economic vulnerability due to job losses in sectors relying more on physical presence, such as the service industry. Understanding these disparities is crucial for updating policies that promote more equitable and sustainable mobility.

This chapter aims to provide a comprehensive overview of the immediate and long-term effects of the pandemic, the socioeconomic inequalities it has intensified or lessened, and the changes in mobility patterns across different sectors. By understanding these changes, urban planners, policymakers, and researchers can better plan for resilient and equitable urban transport systems. We will highlight not only the challenges faced but also the opportunities that lie ahead for reimagining urban mobility in the postpandemic era. As we move forward from the pandemic, it becomes increasingly clear that the decisions made today will shape the urban mobility landscape of tomorrow.

The rest of this chapter is organized as follows. Section 19.2 examines the immediate impacts of the pandemic through a literature review and a case study. The case study focuses on the geographic heterogeneity of urban mobility changes during COVID-19. Section 19.3 dives into changes within specific sectors such as public transportation, tourism, retail, and commuting. Section 19.4 discusses the policy implications and future outlook of urban mobility in a world that continues to adapt to the realities after COVID-19. We conclude this work in Section 19.5.

19.2 THE IMMEDIATE IMPACTS OF COVID-19 ON URBAN MOBILITY

As mentioned in Section 19.1, the COVID-19 pandemic brought about immediate and significant changes in urban mobility patterns worldwide (Gao et al. 2020; Xiong et al. 2020). With the enforcement of lockdowns, stay-at-home mandates, and travel restrictions, there was a dramatic reduction in movement within cities. People drove less, and public transport usage significantly declined (Bouzaghrane et al. 2024). For instance, the Netherlands experienced a dramatic reduction in travel during the early lockdown period (van der Drift, Wismans, and Olde Kalter 2022).

The pandemic inevitably triggered changes in activity patterns and schedule habits. Contrary to the expectations that flexible work arrangements and telecommuting would lead to more irregular schedules, people developed stronger schedule habits (Edsberg Møllgaard, Lehmann, and Alessandretti 2022; Huang et al. 2020; Islind, Óskarsdóttir, and Steingrímsdóttir 2020). This suggests a complex relationship between the pandemic and individual behavior. A longitudinal study from the United States revealed that while certain mobility indicators, like the number of weekly trips, returned to prepandemic levels, others such as at-home dwell times were still quite different from prepandemic times, which suggests a permanent behavioral shift (Nikiforiadis et al. 2022).

To illustrate these changes through a case study, we analyzed the 10 most populated Metropolitan Statistical Areas (MSAs) in the United States during the summer months (June to August) of 2019 and 2020. The mobility data were sourced from SafeGraph's Social Distancing Metrics V2.1 (SafeGraph 2021). The Mobility Index (MI) measures the proportion of devices not stationary at home relative to the total number of observed devices. This is a helpful indicator for understanding general mobility's activeness among the population.

In the summer of 2020, all 10 MSAs saw significant reductions in MI compared to 2019. For instance, in the Washington MSA, the mean MI decreased by 0.08. This decline reflects compliance with movement restrictions, stay-at-home mandates, travel restrictions, and business closures aimed at limiting virus spread. Notably, in early August 2020, the Miami MSA experienced a significant drop in MI from 0.71 on July 31 to 0.58 on August 2. This significant decrease reveals that a considerable number of residents decreased their trips outside the home during that time. This decline could be attributed to increased awareness and caution following the summer surges in COVID-19 cases. Additionally, localized health advisories, travel restrictions, and lockdown measures likely urged people to stay home.

Examining the geographic distribution of MI offers further insights into how mobility behaviors adjusted to COVID-19 restrictions. As shown in Figures 19.1 and 19.2, in the New York MSA, coastal areas were more active before COVID-19, with higher MI values. During the pandemic, the pattern became more scattered, indicating a broader distribution of mobility across the region. This dispersion can be attributed to strict lockdown measures and individual health concerns that pushed people to avoid crowded city centers and the shift to remote work.
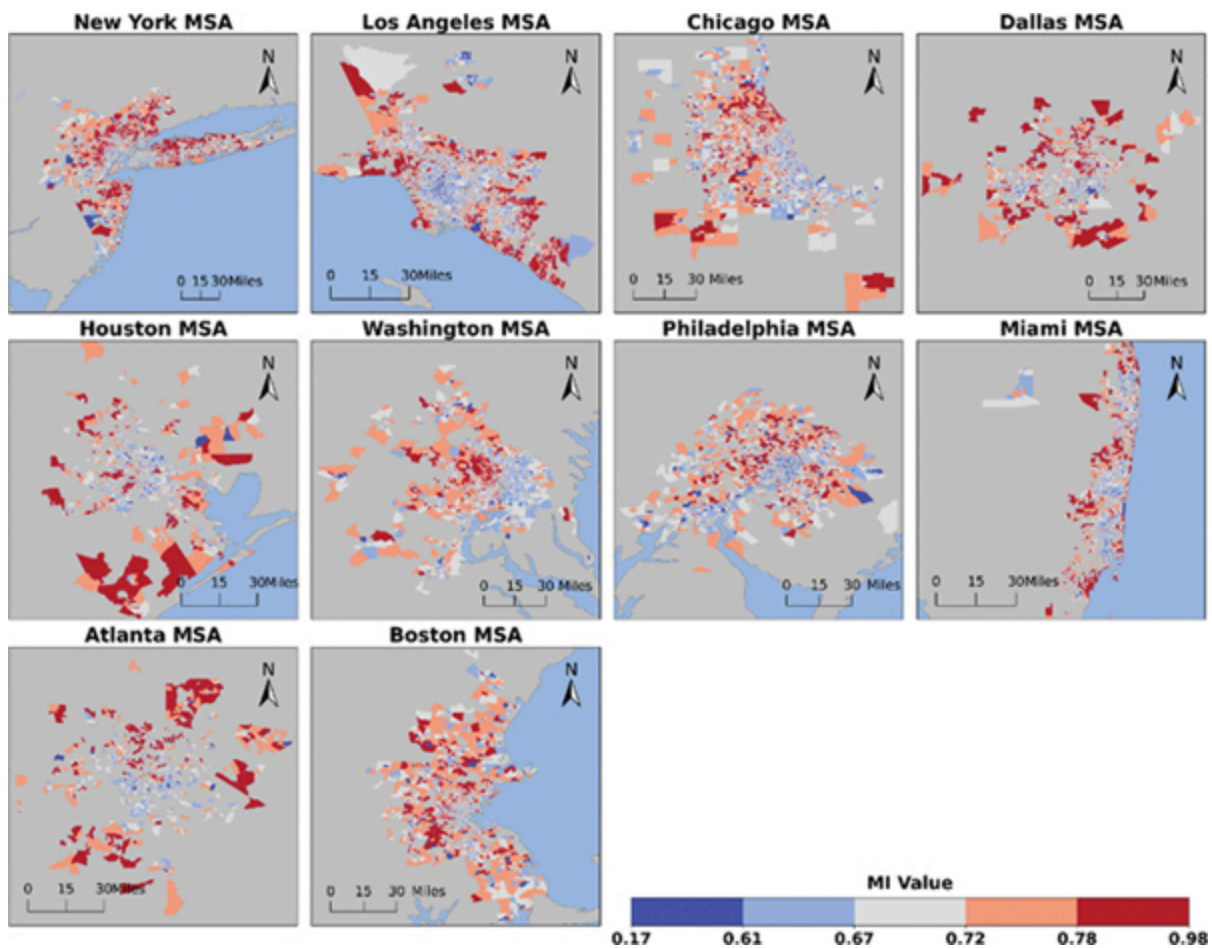
FIGURE 19.1 Distribution of Mobility Index (MI) in summer of 2019 across the 10 Metropolitan Statistical Areas (MSAs).
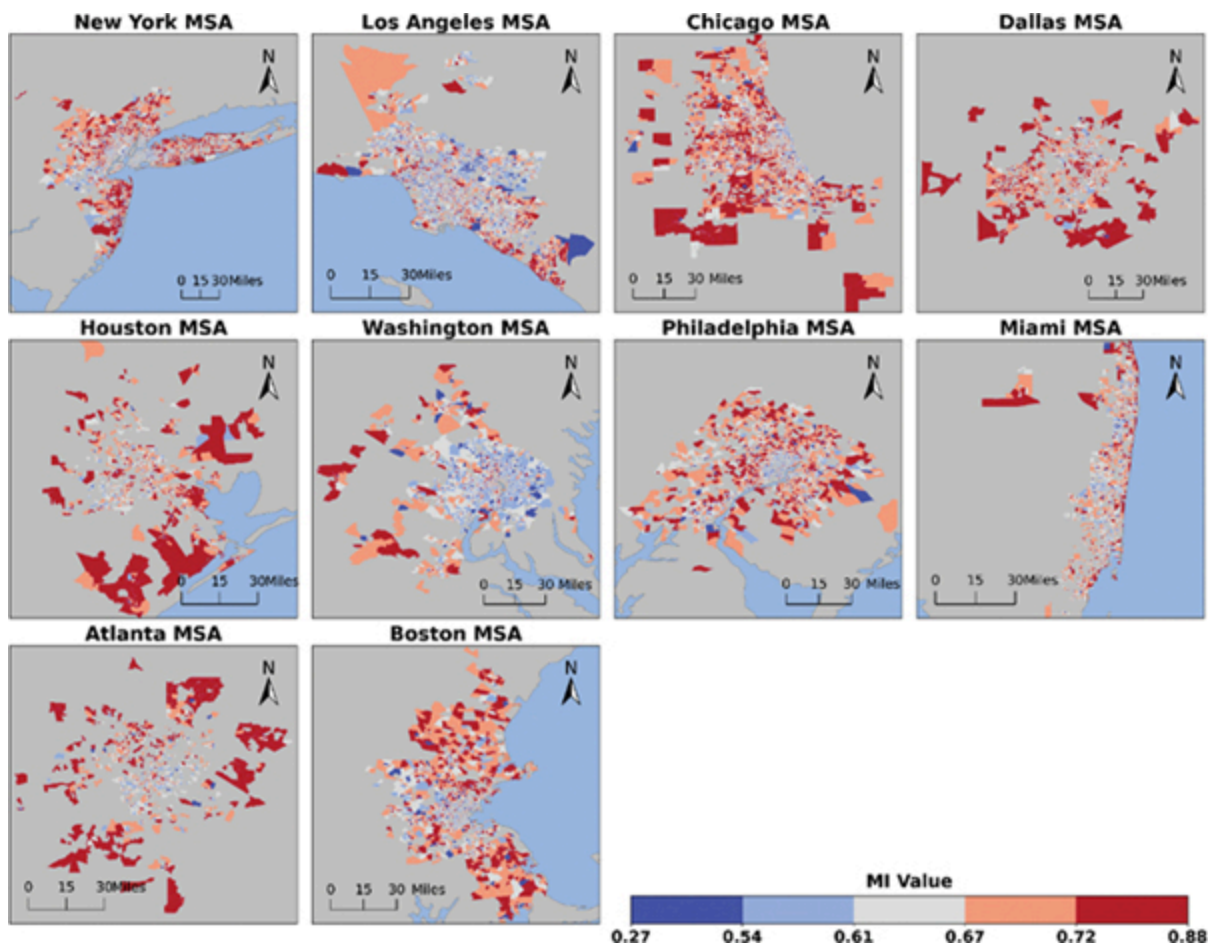
FIGURE 19.2 Distribution of Mobility Index (MI) in summer of 2020 across the 10 Metropolitan Statistical Areas (MSAs).

In the Los Angeles MSA, peripheral census block groups (CBGs) were more active in 2019. During COVID-19, coastal areas became more active. This shift likely reflects people's preference for outdoor spaces and less densely populated areas.

On the contrary, before COVID-19, mobility was relatively scattered across the midwestern and southern MSAs, such as Chicago, Dallas, Houston, Philadelphia, Atlanta, and Boston. However, during the pandemic, mobility patterns shifted to focus on the peripheral areas. This change suggests a migration to suburban or rural areas to work remotely or minimize health risks while still participating in economic activities.

In the Washington MSA, high MI value was concentrated in the central region before COVID-19 but shifted westward during the pandemic. This move suggests a preference for less densely populated neighborhoods while maintaining proximity to economic activities. Similarly, in the Miami MSA, mobility was concentrated near coastal areas in 2019. However, during COVID-19, these areas saw reduced MI values, while inland regions showed increased mobility.

These geographic shifts highlight how mobility behaviors adjusted to COVID-19 restrictions, revealing regional disparities and new trends in mobility patterns. Overall, these patterns reveal a clear shift in mobility behavior during the pandemic, reflecting not only reductions in movement but also changes in how people adjusted their activity habits during this time.

Meanwhile, the pandemic highlighted existing disparities in transportation use (Sy et al. 2021; Wang et al. 2022) and residential mobility (Iglesias et al. 2019), where movement between neighborhoods varied based on socioeconomic contexts (Modai-Snir and Plaut 2019). The pandemic's impact on urban mobility was uneven across socioeconomic groups (Hong et al. 2021), with lower-income and less-educated individuals continuing to travel more due to their inability to work remotely (Brough, Freedman, and Phillips 2021). They faced higher

viral exposure due to economic necessity and less favorable home conditions for prolonged isolation. Counties with a higher level of social poverty also showed a greater increase in COVID-19 cases and deaths, underscoring the disproportionate impact of the pandemic on disadvantaged communities (Garnier et al. 2021; Lucchini et al. 2023; Ossimetha et al. 2021). Understanding the diverse impact of the pandemic on different groups is crucial for developing equitable transportation policies and infrastructure that support all demographic groups, especially the most vulnerable. Future urban planning must prioritize resilience and accessibility to ensure that all communities can navigate both everyday life and crises effectively.

19.3 SECTOR-SPECIFIC CHANGES IN URBAN MOBILITY

In this section, we review the pandemic's impact on various sectors, such as public transportation, tourism, retail and service, and so on. These sector-specific changes offer insights into how urban mobility and economic activities have been reshaped by the pandemic, which provides a foundation for future planning and policy development.

19.3.1 Public Transportation

The pandemic's long-term impacts on commuting behavior were notable, with a shift from public transport to individual transport modes such as personal cars and motorcycles (Badr et al. 2020). This shift was primarily driven by the perceived risk associated with different transportation modes during the pandemic (Dingil and Esztergár-Kiss 2021). In particular, the COVID-19 pandemic greatly impacted global urban transportation systems, particularly public transportation.

Ridership dropped across various countries and regions due to health concerns, lockdown measures, and other related factors (Hu and Chen 2021; Lin et al. 2023; Qi et al. 2023; Vickerman 2021). For instance, during the pandemic peak, tube and bus trips in the United Kingdom dropped by 94% and 83%, respectively (Qi et al. 2023). In the United States, Chicago was hit hard, with 95% of transit stations experiencing significant impacts and an average ridership decline of 72.4% (Hu and Chen 2021). Lin et al. (2023) analyzed public transit usage in Jeju, South Korea, using a 2-year smart card dataset, and they observed clear distinctions in hot spots of public transit usage at a station level during different pandemic stages (Figure 19.3). The authors found clear spatial heterogeneity in terms of public transit ridership changes. The ridership in popular areas, such as tourist sites, declined more substantially when the pandemic situation was severe, as people were likely to take caution and avoid possibly crowded sites.
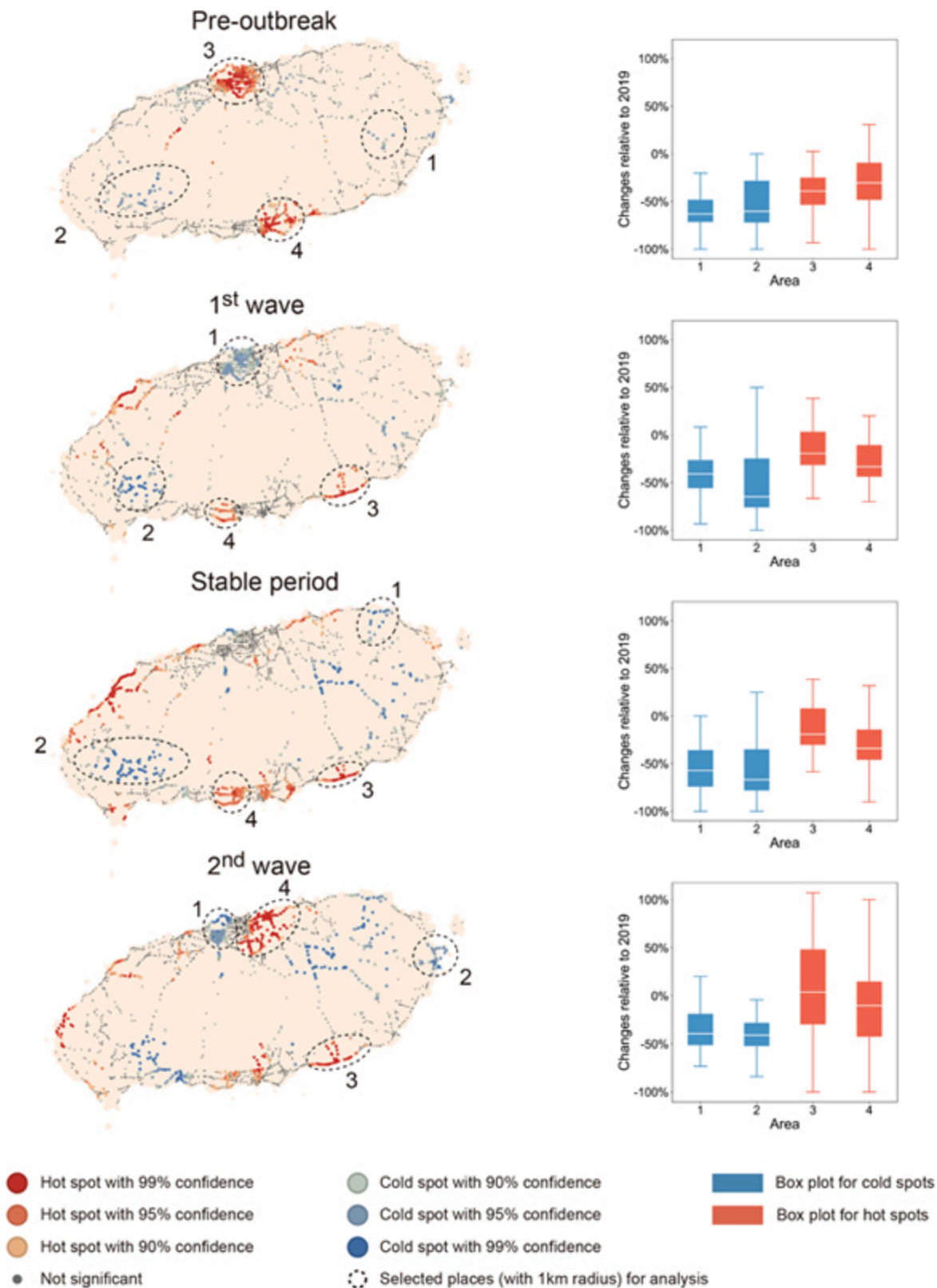
FIGURE 19.3 Observed hot spots of the changing public transit ridership at station level during the four pandemic stages. (This graphic was reproduced from Figure 7 in Lin et al. [2023] with written permission from the authors and publisher.)

As the pandemic eased, there was a general rebound in the use of public transportation. However, recent statistics from the United Kingdom indicated that public transport usage has not yet fully returned to its prepandemic level (Department for Transport 2024). This partial recovery can be attributed to several factors. First, the perception of risk continues to influence individuals' willingness to use public transit (Dong et al. 2021; Lin et al. 2024). The fear of being infected by the virus in crowded spaces like buses and trains deterred

many people from using these public services. Second, the rise of telecommuting and remote working has had a profound effect on commuting patterns. With more people working from home, the demand for daily commutes has decreased, leading to a reduction in peak-hour traffic and, consequently, a decreased need for public transportation services (Vickerman 2021). Many companies have adopted hybrid work modes, which means fewer employees are traveling daily, impacting the overall demand for public transit.

In the postpandemic era, there has been a noticeable shift toward alternative modes of transportation. In many cities, the use of active transportation methods such as walking and cycling has increased, and these transportation methods are considered safer and more sustainable (Xu et al. 2023; Li et al. 2021). To support this shift, some cities have redefined road spaces, enhanced infrastructure, invested in facilities to accommodate bicycles and scooters, and encouraged the adoption of these modes of transport (Aloi et al. 2020; McKinsey 2020). This shift toward active transportation is not only a response to the pandemic but also a step toward achieving sustainability goals.

To sum up, the COVID-19 pandemic has reshaped public transportation. Although there has been a partial return to prepandemic usage levels, the long-term effects of increased health risk awareness, the rise in remote working, and a shift toward more active and sustainable transportation modes remain significant. These changes, although presenting challenges, offer cities a unique opportunity to transition toward more sustainable transportation systems.

19.3.2 Tourism and Travel

The tourism industry was one of the sectors hit the hardest by the COVID-19 pandemic, with travel restrictions and health risks significantly reducing tourist flows, leading to significant economic losses (González-Torres et al. 2021; Ren et al. 2022; Yang et al. 2020). During the pandemic, nearly 96% of the global population experienced some form of international travel restrictions, which resulted in a far-reaching impact on global tourism (Gössling et al. 2020; UNWTO 2020).

In response to the pandemic, there was a notable change in tourist flows and destination preferences. Historically popular and densely populated tourist hot spots experienced a decline in visitor numbers as travelers sought safer, less crowded alternatives. This led to a surge in interest toward remote, less populated destinations, which were considered to be safer and more controlled (Zenker and Kock 2020).

With the relaxation of travel restrictions, the phenomenon of "revenge travel" emerged, reflecting a surge of enthusiasm and urgency to resume travel and make up for lost time (Abdullah 2021). This trend is characterized by a rebound in demand for travel to fulfill postponed travel plans. Despite the rebound in demand, fear of traveling continues to linger among certain populations due to ongoing concerns about health and safety (Zenker et al. 2021). In addition, "untact" tourism has gained attention, particularly in South Korea, where minimizing physical contact has become a top priority in reducing health risks (Bae and Chang 2021). This trend has led to the rise of self-driving tours and camping, allowing tourists to enjoy their vacations while maintaining social distancing.

The accelerated digitalization of tourism has been another significant development. Virtual reality (VR) and augmented reality (AR) technologies have provided innovative ways for individuals to experience destinations from the comfort of their homes. This trend has not only provided a safe alternative for travel during the pandemic but also made tourism more accessible to those who are unable to travel due to physical or financial constraints (Talwar et al. 2023). Furthermore, the rise of the "workation" trend—where individuals merge work and leisure—has also shaped new travel patterns. This trend has been facilitated by the rise of remote work, allowing individuals to work from anywhere with a stable Internet connection (Bassyiouny and Wilkesmann 2023).

Overall, the postpandemic era has brought a range of new trends and changes to the tourism and travel sector, driven by changing behaviors, technological advancements, and evolving health and safety priorities. These developments will likely define the future trajectory of global tourism.

19.3.3 Retail and Services

Retail and service businesses in urban areas saw a significant decline in foot traffic as lockdowns and health concerns kept people at home (Rajpurohit 2021; Shah 2021). For instance, the foot traffic near stores in metropolitan areas remains 10% to 20% below prepandemic levels (Mischke et al. 2023). However, the number of active stores was almost the same as pre-COVID levels, with most store closures happening among independent stores, particularly in smaller municipalities. Independent stores accounted for over 90% of the overall decline in active stores and more than 70% of the drop in total foot traffic volume (Wang 2023).

The drop in foot traffic led to a rethinking of store accessibility. Retailers began to focus more on integrating new digital technologies with traditional retailing (Kotb 2020). For example, some added social media sales to their services (Cruz-Cárdenas et al. 2021). In the Puget Sound area, online shopping is a substitution for in-store shopping for groceries, while it complements in-store shopping for food and other items (Diaz-Gutierrez, Mohammadi-Mavi, and Ranjbari 2023). The number of businesses that operate both online and physical locations, known as click-and-mortar businesses, also grew during this period (Lashgari and Shahab 2022).

In addition, businesses had to innovate to survive the new normal. Many turned to delivery and curbside pickup models to maintain sales. For example, some added home delivery services to their previous services (Cruz-Cárdenas et al. 2021). Many businesses offered free contactless home delivery services and click-and-collect options (Grimmer 2022). Some restaurants expanded their delivery services, partnering with platforms like Uber Eats and Deliveroo (Ecker and Strüver 2022, Goodman 2023).

Additionally, some services went digital. Health and wellness services, like fitness classes and therapy sessions, moved online, offering virtual appointments (Silva-Jose et al. 2022; Wu et al. 2023). Retailers also invested in technology like augmented reality to allow customers to "try on" clothes or see how furniture would look in their homes without visiting a store (ICE Cobotics 2024; ThinkSys Inc. 2023). These changes in urban mobility for the retail and service sectors may have lasting effects, pushing businesses to continue integrating flexible, customer-centric service delivery models.

19.3.4 Work and Commuting

The shift to remote work during the pandemic has also been highlighted in studies across various disciplines like geography, transportation, urban planning, and economics. Studies show that remote work has reduced the need for commuting and contributed to a decrease in urban traffic congestion and emissions (Beck and Hensher 2020; Florida, Rodríguez-Pose, and Storper 2023; Lennon 2023). These studies also highlighted the potential long-term changes in how cities might be planned with a focus on resilience and sustainability.

However, this transition also emphasized the digital divide that may affect productivity and accessibility (Fairlie 2020). The digital divide describes the gap between demographics and regions that have access to modern information and communication technology and those that do not, and this issue became increasingly significant with the increase in teleworking. This divide affects not only access to technology but also the capability to engage effectively in a remote environment. A broader analysis by Robinson et al. (2020) highlighted how different levels of access to high-speed Internet and digital literacy skills can impact employee productivity and job opportunities. Without strategic interventions, the digital divide may cause bigger socioeconomic inequalities, particularly in less urbanized areas.

19.4 POLICY IMPLICATIONS AND FUTURE OUTLOOK

As discussed in Sections 19.1–19.2, the COVID-19 pandemic prompted a reevaluation of urban mobility and transport policies within cities. Here we review the policy implications and discuss the outlook of human mobility, current strategies adopted by cities, and recommendations for urban planners in the postpandemic world.

19.4.1 Strategies Implemented by Cities

As the pandemic accelerated existing trends like remote work and food delivery, it fundamentally altered urban life (Edsall 2022; Lai et al. 2020; Sharifi and Lee 2024). A key focus for city officials and transportation planners has been adapting to changing mobility patterns. Interestingly, many of these mobility strategies align with broader climate change goals. Here, we synthesize some of the broader strategies being implemented.

- *Urban Space Redesign*: Cities have responded by implementing various urban redesign initiatives to create more resilient, equitable, and healthy environments. To accommodate evolving mobility demands, urban centers have expanded bike lanes, implemented bike-sharing programs, and created pedestrian-friendly zones. Some cities have even closed streets to traffic, either seasonally or permanently. The concept of "pop-up" infrastructure has emerged as a strategy for rapid adaptation to changing conditions (Moran 2022).

  Green spaces have also gained prominence as essential components of urban well-being (Noszczyk et al. 2022). Cities are investing in parks, green roofs, and urban forests to improve air quality, mitigate climate change, and provide spaces for community engagement. These spaces are being designed with accessibility and inclusivity in mind, making them destinations for residents from all backgrounds (Jian, Luo, and Chan 2020).

- *Changes to Public Transport*: Vulnerabilities in public transportation systems were exposed during the pandemic, forcing transport officials to make substantial changes. Responses came in the form of adjusting schedules, managing capacity, and reconfiguring routes. Initially, diminished ridership led to reduced service frequency. As restrictions eased, cities increased service levels (UITP 2024) while grappling with the challenge of ensuring essential workers' mobility. On-demand transit and schedule prioritization for essential works (often from lower-income communities) have emerged as potential solutions (Ashour et al. 2024).

  To address safety concerns, capacity limitations were implemented through measures such as passenger limits and seat-blocking (ITF 2023). While these restrictions are easing, capacity management remains crucial. Furthermore, altered travel patterns, including increased commuting to suburban areas and the rise of e-commerce, prompted route adjustments. Cities are adapting their networks to better serve these evolving transportation needs (APTA 2021).

- *Technology Integration*: The pandemic also accelerated the adoption of technology in urban transportation. Smart city initiatives that leverage sensor data and analytics are growing in interest (Megahed and Abdel-Kader 2022). These systems offer insights into mobility patterns, congestion, and public health concerns. Contactless payment systems, while massively beneficial for tracking and efficiency, have also raised concerns about accessibility for lower-income individuals (Golub et al. 2022).

- *Environmental Implications and Strategies*: It is worth mentioning that all these monumental shifts in mobility patterns led to a noticeable decrease in air pollution and greenhouse gas emissions. Cities around the world reported cleaner air and improved air quality indices (Slezakova and Pereira 2021). While emissions have rebounded (ESA 2021), cities are working to sustain these gains. Strategies to enhance air quality include promoting remote work, expanding public transit, and investing in active transportation infrastructure. A shift toward electric vehicles, both personal and shared (e.g., buses), is also underway. These initiatives address both climate change and public health concerns. Governments are implementing long-term environmental policies. These include carbon pricing (Kennedy, Ibrahim, and Hoornweg 2014), prioritizing low-carbon development and green spaces (Nieuwenhuijsen 2021), investing in clean(er) technologies (Hoang, Nguyen, and Others 2021), and collaborating across agencies, cities, and governments to address global climate change challenges.

19.4.2 Outlook and Recommendations

While cities have made significant strides in adapting to these changes, the path toward resilient, sustainable, and equitable urban mobility is long. To build upon the progress made, cities must prioritize long-term strategies that foster resilience, inclusivity, and environmental sustainability. Investing in sustainable infrastructure, creating adaptable urban environments, and ensuring equitable access to transportation are important steps toward achieving these goals. To prioritize public health, cities must continue to improve hygiene measures and capacity management and invest in real-time data collection and analytics. To enhance urban mobility resilience and promote equitable transportation solutions in the postpandemic world, we suggest that city officials, transportation planners, and policymakers focus their efforts on a few key areas, including but not limited to the following areas:

- *Invest in Sustainable and Resilient Infrastructure*: Cities should prioritize infrastructure that supports sustainable and adaptable mobility. This includes expanding public transportation options like electric buses and trains, as well as investing in bike-sharing systems. Additionally, continuing to implement smart technology to collect and analyze transportation data is essential for optimizing traffic flow, public transit schedules, and resource allocation.

- *Build Adaptive and Flexible Urban Systems*: To withstand future disruptions, cities must design flexible transportation systems. This involves creating multimodal spaces that can accommodate various transportation modes, such as bikes, e-scooters, cars, and buses. Infrastructure should be adaptable to rapidly changing mobility patterns, ensuring the city can respond effectively to future crises.

- *Prioritize Equity and Inclusion in Transportation*: Equitable access to transportation for all residents, including those in underserved communities, is essential. Those in marginalized communities were most impacted by the most recent global pandemic, so every effort should be made to engage with these communities when investing in accessible mobility solutions. Cities must address the disproportionate impact of transportation challenges on marginalized communities through targeted investments and inclusive policymaking. Meaningful community engagement is essential for developing transportation solutions that meet the diverse needs of the population.

Realizing these ambitions requires a proactive and adaptive approach, and continuous monitoring and evaluation of transportation policies and programs are essential for identifying emerging challenges and seizing new opportunities. A data-driven and evidence-based approach, coupled with active public engagement, will be instrumental in shaping the future of urban mobility.

19.5 CONCLUSION

In conclusion, the COVID-19 pandemic has caused lasting changes in urban mobility and revealed the vulnerabilities within our transport systems. This chapter comprehensively examined these shifts, their immediate impacts, enduring changes, and the broader implications for urban planning and policy. As we reflect on the past few years, it is evident that the pandemic did not merely disrupt normality in our lives; it also pushed us into a period of rapid adaptation and reevaluation of our urban spaces and mobility frameworks.

The initial shock of the pandemic resulted in a dramatic reduction in movement, as observed in Section 19.2. This reduction was not just a temporary response but has led to lasting changes in how we view and utilize transportation. Public transportation, for instance, has seen fluctuating ridership with a persistent concern about health risks. Meanwhile, the surge in alternative modes of transport like walking and biking underscores a shift toward more sustainable and health-conscious urban mobility. These shifts, while challenging, offer cities an unprecedented opportunity to reimagine and redesign urban spaces for greater sustainability, resilience, and equity.

Moreover, the pandemic has exposed the socioeconomic disparities in urban mobility, which demands a more focused approach to ensure that transportation systems are inclusive and equitable. The alleviated vulnerability of certain demographic groups during the pandemic has highlighted the need for policies that do not merely return to the prepandemic status quo but strive to rectify these inequalities. As cities plan going forward,

integrating technology and innovative transport solutions will be key in developing responsive and adaptive urban transport systems that cater to the needs of all citizens.

Looking ahead, the resilience of urban mobility systems will heavily depend on the lessons drawn from this pandemic. Policymakers, urban planners, and researchers must collaborate to harness the insights gained from these difficult times to foster transportation systems that are not only efficient but also robust and inclusive. The path forward should aim not just to recover but to transform urban mobility in ways that better prepare cities for any future challenges.

This reevaluation and transformation of urban mobility are not merely a response to a crisis but proactive steps toward future-proofing our cities. As we navigate out of the pandemic era, the decisions we make today will undoubtedly shape the landscape of urban mobility for generations to come, ideally toward more equitable, sustainable, and resilient urban environments.

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