# Introduction

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**Abstract** This introductory chapter discusses the book's scope and structure and gives a brief summary of the 20 chapters that follow. The COVID-19 pandemic brought urban life all over the world at a standstill. It dramatically affected mobility and had ripple effects on the economy, environment, and safety of urban areas. But not all urban residents were affected equally. The chapter introduces the major research topics and questions, which are addressed collectively by the book's contributors. These include (1) the impacts of the pandemic on vulnerable populations; (2) the impacts on the transportation industry and other sections of the economy that rely on the transportation sector; (3) the impacts on alternative forms of work, shopping, and travel; (4) the impacts on environmental quality and traffic safety; and (5) the lessons that the phenomena observed during the pandemic may entail for policymakers and transportation planners.

Mobility—the ability to move from one place to another smoothly, quickly, and without impediment—has been the epitome of modernity. Mobility has been valued as it is associated with accessibility—the ability to access and take advantage of urban amenities such as schools, hospitals, supermarkets, or parks, but also jobs, which are distributed across a metropolitan landscape. For this reason, physical mobility is often linked to opportunities for the achievement and enjoyment of a better life in cities. Mobility is bolstered by the availability and smooth integration of multiple transportation modes, including opportunities for walking and biking. Indeed, great cities are also characterized by high levels of mobility among their residents and by good transportation networks.

But what happens when urban mobility is greatly disrupted by a catastrophic event—an event that comes unexpectedly and lasts for multiple months or even years? This dystopic scenario is exactly what happened in cities around the world during the COVID-19 pandemic. Emerging first in Wuhan, China in the waning days of 2019, the pandemic proceeded to spread fast throughout the globe, partly facilitated

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by inter- and intra-urban and long-distance travel. No corner of the world, no matter how remote, remained unaffected or untouched. Certainly, the most significant and sober impact of the pandemic can be measured in the millions of lives that have been lost. But the pandemic also brought cities and urban life as we know it at a standstill. Physical distancing and shelter-in-place mandates and lockdown orders, issued by governments around the world, along with people's fears about the transmission of the disease, curtailed mobility and travel, but have also had ripple effects on the economy, the environment, and on safety in cities and metropolitan areas. The pandemic affected different urban groups differently, often exacerbating pre-existing inequalities and vulnerabilities.

This book explores the impact of the pandemic on mobility and transportation. It examines both its direct impacts on travel and mobility but also the side effects of altered or disrupted travel patterns. Thus, it also explores some of the by-products of diminished mobility—such as the proliferation of telecommuting and e-commerce, reduction of greenhouse gas emissions, and decreased traffic crashes. It collectively aims to address the following questions.

- How has the pandemic impacted vulnerable populations in cities differently?
- What have been the impacts of the pandemic on the transportation industry (in particular public transit) but also on other industries of the economy that rely on transportation (such as freight trucking, retail, and food industries, or the gig-economy)?
- How has the pandemic affected automobile traffic and associated air quality and traffic safety?
- How has the pandemic bolstered alternative forms of work (telecommuting), shop (e-retail), and travel (walking and cycling), and are the altered patterns likely to persist?
- Importantly, what have been some positive responses to the transportation and mobility challenges? What lessons can policymakers, planners, and transportation officials learn from the pandemic? Can the condition of and reaction to the pandemic spur positive changes in urban transport?

## 1 Book Organization

The book is a compilation of 19 chapters, in addition to Introduction and Conclusion. The chapters are arranged in two parts: Impacts and Responses. The impacts are further divided into four sections: Vulnerable Populations, Economy, Environment and Safety, Mobility and Travel. All chapters represent empirical, data-driven, and original research work. The authors are affiliated with the University of California Institute of Transportation Studies (ITS) (https://www.ucits.org/)—a flagship multi-campus research institute on transportation and policy in the United States and in the world. ITS spans the UC Berkeley, UC Davis, UC Irvine, and UCLA campuses and other affiliated universities of the University of California system. While a number of chapters focus particularly on California, the largest and most diverse U.S. state and

the largest state economy in the United States, other chapters also draw information from other geographic contexts. The concluding chapter builds on the previous chapters to summarize the collective wisdom and major findings and extrapolate lessons for cities and metropolitan areas, as well as for future research and policy.

## 2 Summary of Contributions

The economic fallout of the pandemic has hit low-income families the hardest. One of the consequences is delinquent car loans, as families who have seen their household income decrease cannot make car payments. In Chap. 2, Evelyn Blumenberg, Fariba Siddiq, Samuel Speroni, and Jacob L. Wasserman examine this issue in California, drawing on data from the University of California Consumer Credit Panel, a dataset that includes anonymized consumer credit and debt data for all California residents, including data on vehicle debt and loan delinquency. They compare the impacts of the Great Recession in the United States (from 2007 to 2009) with the impacts of the COVID-19 pandemic (2020–2021) on car loan delinquencies and analyze their data across neighborhoods by income and race. They find that the crisis affected low-income, minority households the most, as these households saw their automobile burden grow. Loans to buy a car slowed down in California during the pandemic, and the burden of automobile debt decreased overall. Nevertheless, the lower rates of automobile borrowing were offset by rising automobile prices, especially for used vehicles. This represented a true hardship for economically vulnerable populations, many of whom are essential workers, who cannot afford to stop working but also cannot afford their cars. The chapter points to the need for policies to better support the transportation needs of lower-income households, especially under shocks such as the one caused by the pandemic.

As homeless shelters reduced their capacity to uphold physical distancing requirements, unhoused individuals were most hardly hit by the pandemic. Many of them had no other places to go to than bus stops, station platforms, and transit vehicles. In Chap. 3, Anastasia Loukaitou-Sideris, Jacob L. Wasserman, Ryan Caro, and Hao Ding inquire about the impact of the pandemic on homelessness in the transit environments of the United States and Canada, and how transit agencies in these two countries have responded to it. They present the results of a survey of 115 transit agencies, finding that the vast majority of these agencies perceive that homelessness has increased in their systems during the pandemic. As most transit riders shunned using buses and trains out of the fear of getting infected, the unhoused riders became more visible. Most transit agencies responded by adopting a range of measures, some positive for their unhoused riders but some also punitive toward them. The chapter points to the importance of outreach strategies that offer help and services (for example free transportation) to unhoused individuals and uphold the social role of transit in cities. It also underlines the need for external public funding for agencies that could help them put in place outreach strategies.

Low-wage workers of the gig-economy represent a vulnerable group, as they receive few (if any) employee benefits and have to work for low wages. The pandemic forced some gig economy workers to shift from driving people in ride-hailing operations to delivering food and groceries for Uber Eats, Instacart, Grubhub, or Door-Dash, without access to personal protective equipment. In Chap. 4, Amelia Regan and Nicola Christie review the recent academic and gray literature to examine the impact of the pandemic on the gig economy and its workers—especially the labor, safety, and environmental impacts. Despite the importance of food delivery and other delivery services during the pandemic, many transportation workers in the gig economy made less than the minimum wage. The outcome of labor issues in some countries, such as the prospect of gig worker unionization or the gig industries' efforts to classify their workers as independent contractors, does not necessarily relate to the pandemic but will affect gig workers' welfare in the future. The safety of transportation gig workers also is a concern as the pressure to complete rides in tight schedules often leads to higher rates of crashes. Lastly, the environmental impacts of the transportation gig economy are mixed. There are demonstrated positive environmental impacts of food delivery services, and pooled ridesharing would result in less vehicle miles traveled (VMT) overall, but the pandemic made people reluctant to use shared ride-hailing services.

Turning to transportation-related economic effects of the pandemic, Hannah King, Natalie Amberg, Jacob L. Wasserman, Brian Taylor, and Martin Wachs examine in Chap. 5 the pandemic's impacts on California's Local Option Sales Tax (LOST), a tax that is levied on the price of all goods and services that are subject to sales taxes (including fuel purchases). Many counties around the United States employ such a tax as a revenue source for funding transportation infrastructure and services (i.e., roadways, bikeways, transit services, transportation services for elderly and disabled people). But unexpected revenue shortages can inhibit the capacity of counties and cities to provide some of these services. The authors find that revenues from LOST fell during the initial stages of the pandemic in all California counties. LOST revenues increased again after the initial months but with variations across counties. Counterintuitively, counties with higher-income households and concentrations of employment in information and professional services, arts, and recreation, lost more revenues from decreased LOST. Not surprisingly, where unemployment rose, LOST revenue fell. This chapter points to the need for policymakers to incorporate uncertainty in revenue projections from taxes such as LOST and prioritize transportation infrastructure and projects, which are typically funded from such revenue sources. The chapter also underlines the importance of federal stimulus funding, which partly covered the lost tax revenues.

Decreases in physical mobility meant that shopping from brick-and-mortar establishments would also fall. In Chap. 6, Miguel Jaller and Sarah Dennis examine the interrelationship between shopping, and mobility trends in the United States, UK, and France and use data from several sources to track people's mobility, shopping and e-shopping patterns, and time spent at home versus work. They find that in all three countries, shopping-related mobility decreased during the first months of the pandemic, as people started spending more time at their homes, but eventually started

catching up pre-pandemic trends. At the same time, e-commerce saw a major boost in all three countries; a trend that has been largely maintained, even if mobility started increasing again. The authors pinpoint to some positive effects of reduced travel (less congestion, cleaner air) but warn that we need clear and deliberate policies and strategies to maintain any mobility benefits experienced during the early months of the pandemic.

In Chap. 7, Jean-Daniel Saphores, Lu Xu, and Bumsub Park also focus on e-commerce for food, analyzing the impacts of the pandemic on how people in California, China, and South Korea shopped for groceries and meals. In contrast to China and South Korea, very few people in California shopped for groceries online, prior to the pandemic. The pandemic changed this trend, with many more Californians ordering groceries online, requesting food deliveries, or using "click-and-pick" to shop groceries. Similarly, China and South Korea, two countries with well-established platforms for e-grocery sales, saw their sales in this sector increase even more as a result of the pandemic and the initiation of innovations such as contactless delivery (dropping packages at designated locations) and livestreaming e-commerce in China, and development of a variety of pre-packaged or instant meal products in South Korea. The authors predict that most e-grocery gains will remain post-pandemic, but their implications for Vehicle Miles Travelled (VMT) are less clear. They recommend zoning changes that would allow e-stores that can fulfill e-orders locally; but also paying attention to equity issues so that poor neighborhoods also receive good e-grocery services.

A surge in e-commerce translates to higher trucking activity. The pandemic affected supply chains globally and created significant bottlenecks in freight movement. In Chap. 8, Yiqiao Li, Andre Tok, Guoliang Feng, and Stephen G. Ritchie investigate the impacts on freight trucking activity in California, looking in particular at changes in drayage, long- and short-haul movement, and payload characteristics. They find that the counts of containers at the Port of Los Angeles initially decreased but later increased, a fact that affected truck activity. Drayage truck movements serving large warehouses increased, while those serving warehouses of smaller businesses decreased. Short-haul truck movements increased significantly, while long-haul truck movements witnessed a small decrease. The pandemic saw a significant increase in full-load tracks and a slight reduction in empty trucks. The authors note that the aforementioned changes are a consequence of changed consumer behavior and needs during the pandemic but also changes in local and foreign policies and supply-chain bottlenecks.

The changes in mobility patterns because of the pandemic have not only brought about economic and social impacts but have also affected air pollution levels. In general, less traffic means less pollution; however, significant disparities were observed in air-pollution levels during the pandemic across neighborhoods, based on their sociodemographic characteristics. In Chap. 9, Shams Tanvir, Dwaraknath Ravichandran, Cesunica Ivey, Matthew Barth, and Kanok Boriboonsomsin explore how the pandemic affected mobility across different communities in Southern California and the associated changes in pollutant concentration. They find that freeway traffic dropped as low as 50% within 6 weeks from California's lockdown, with

associated reductions in transportation-related air pollution. However, traffic gradually increased to pre-pandemic levels. The authors note significant differences in traffic volume changes across the region based on neighborhood sociodemographic characteristics, with traffic flows rebounding faster in disadvantaged neighborhoods. Indeed, the more disadvantaged a community, the less traffic reduction and air pollution reduction it experienced. Such disparities accentuate already existing environmental justice concerns in the region. The authors propose the development of telecommuting programs for low-income employees, as well as ensuring that the expansion of warehousing activities (because of e-commerce proliferation) does not further penalize disadvantaged communities.

In Chap. 10, Fraser Shilling expands the inquiry about pandemic-related environmental impacts, estimating the reduction in greenhouse gas (GHG) emissions because of reduction in VMT, as well as the associated change in fuel tax revenue throughout the United States. He finds that, thanks to a 50% reduction in VMT, GHG emissions in the United States were reduced by 4% in total and by 13% from transportation in the 8 weeks following stay-at-home orders. He estimates that this translates to savings of about $5 billion per week to U.S. drivers, but losses of about $0.7 billion per week in states' tax revenues. California's reduction in GHG has been greater than the U.S. average, and the state's travel rates remained reduced by as much as 20% through the spring 2021, compared to 2019. As the author notes, it is clear that human behavior, similar to the one exhibited during the pandemic, can contribute significantly to long-term reduction of GHG emissions. Policymakers and businesses should consider policies that enable, even incentivize, more work from home but do it in ways that do not exacerbate inequity.

The reduced trip frequency and associated changes in traffic volumes observed during the pandemic influenced the incidence of highway crashes. This is the topic examined by Offer Grembek, Praveen Vayalamkuzhi, and SangHyouk Oum in Chap. 11. The authors analyze crash data on California highways from the California Statewide Integrated Traffic Records System (SWITRS) database, as well as exposure data based on Vehicle Miles Traveled (VMT) as provided by the Caltrans Performance Measurement System (PeMS), for 6 weeks before and 7 weeks after California's Stay Home orders. They also collect crash and VMT data for corresponding weeks during 2019. They find that the total number of injury crashes, across all levels of severity, decreased during the pandemic, as compared to 2019. However, while the overall crash frequency dropped, the rates of severe crashes increased, likely because of less traffic on the highways, which allowed for higher speeds. The authors note that their findings suggest some policy implications for traffic operations such as coupling congestion mitigation measures with safety improvements.

The fear of shared transportation modes in enclosed environments, whether justified or not, led to a preference of individual modes during the pandemic. In Chap. 12, Sean McElroy, Dillon Fitch, and Giovanni Circella examine how the pandemic changed walking and biking habits of adults in the United States. Using data from a longitudinal panel, collected during four time periods between 2018 and 2020 from different regions across the United States, the authors find that walking and biking for commuting trips increased during the pandemic, possibly encouraged by many

cities that designated Open Streets favoring these two modes. At the same time, however, the mode share of private car also increased during the spring of 2020, as people needing to travel longer distances avoided modes that would bring them into close contact with other travelers. The authors emphasize the need for post-pandemic policies that facilitate the use of active travel modes, such as making Open Streets permanent, developing a pedestrian and cycling infrastructure in cities, and offering incentives for e-biking.

Working from home, or telecommuting, became a viable option for many during the pandemic. Indeed, we can say that the pandemic effectively created two major groups: those who worked from home and those who continued to travel to work. Using data from a cross-sectional survey of 4,045 Southern California residents, Jai Malik, Bailey Affolter, and Giovanni Circella examine in Chap. 13 the differences in sociodemographic characteristics and travel behavior between these two groups. They find that non-teleworkers are mostly non-White, younger, and of lower incomes. The authors note a dramatic increase in telecommuting in the region, finding that only 20% of telecommuters were working from home prior to the pandemic. Both groups experienced decreases in their overall trip frequency and VMT across all transportation modes, and shifted to more individual modes such as private automobiles and active travel modes for non-commute travel. During the same time, transit use and shared mobility options such as e-scooters and ride-hailing declined. The authors point to the importance of making these options safe again, while encouraging non-motorized travel where possible.

In Chap. 14, Michael G. McNally, Rezwana Rafiq, and Md Yusuf Sarwar Uddin also focus on changes in telecommuting during the pandemic and the resulting travel behavior. They merge a number of datasets to examine nine months of data from the four largest U.S. states (California, Florida, New York, and Texas) to identify changes in travel behavior, telecommuting, visits to work and non-work places, and average distance traveled. Similar to the findings of the previous chapter, they find that those who telecommuted were more high-income, White or Asian. In all four states, a sharp decrease was observed during the initial outbreak period for all types of trips; however, visits to grocery stores, pharmacies, and parks were among the first types of trips to recover. The researchers find differentiation among the four states in the extent of telework among their residents. California, in particular, had a higher fraction of people staying home and has experienced higher reductions in work and non-work trips than the other three states. The authors note, that in a post-pandemic world, high levels of telecommuting would help lessen traffic congestion and reduce commuting time and cost. However, changes from the part of both companies and policymakers would need to happen to maintain the gains in telecommuting observed during the pandemic.

The use of public transit witnessed a dramatic reduction during the pandemic because of the public's fear of disease spread and infection within the narrow confines of transit vehicles. But to what extent transit use impacts the transmission of COVID-19 in urban areas? Henry Bernal and David Brownstone seek to respond to this question in Chap. 15 using data on station-level ridership and COVID-19 case counts within Countywide Statistical Areas (CSA) in Los Angeles County. They find no

evidence that increased ridership levels or bus trip lengths are associated with higher incidence of COVID-19 at the CSA level in Los Angeles County in the period between June 2020 and January 2021. Indeed, their study suggests that masking and vehicle sanitation measures proved quite effective, and fears of becoming infected because of riding transit may have been exaggerated. However, the authors cautiously note that contact tracing investigations using virus sample genetic sequencing to identify the sources of COVID-19 infections can better confirm if bus ridership does not affect COVID transmission.

While the previous chapters focus more on the mobility-related impacts of the pandemic, the next five chapters focus more on actual or potential responses. The first three of these chapters focus on the transit industry and its responses to the pandemic, using different geographic contexts. Thus, in Chap. 16, Yiduo Huang and Zuojun Max Shen summarize evaluation methodologies, which examine the effectiveness of policies that various transit agencies worldwide have followed in their efforts to prevent COVID-19 transmission in transit environments. They find that if different districts in a city have almost similar infection rates, an effective policy to minimize the spread of the infection in public transportation networks is by reducing the total travel time and crowding levels. On the other hand, if different districts have uneven infection rates, effective policies should seek to reduce the weighted sum of the travel time and crowding levels. They also discuss the impacts on disease spread of reducing bus line capacity or closing lines, as well as of cutting transit budgets. As also discussed in Chap. 15, the authors' models show that the preventive measures against the spread of COVID-19 in U.S. transit environments seem to have been effective.

In Chap. 17, Samuel Speroni, Brian Taylor, and Yu Hong Hwang survey 72 U.S. transit operators to inquire about the pandemic's impact on their agencies and these agencies' response during the initial shock period of three months, a later period of adaptation, and a period of recovery, after March 2021. The authors find that small and large agencies were affected somewhat differently, but overall, they acted fast in response to pandemic mandates and challenges, initiating mandatory masking on vehicles and rear-door vehicle boarding, restricting some seats from use, installing dividers between operators and riders, and practicing extensive cleaning and disinfection. The pandemic increased the visibility of transit's role as social service provider, and many agencies reported developing service and outreach policies targeted toward their more disadvantaged riders. The authors note that while the short-term financial shortfalls of the transit industry were addressed by the federal relief bills, the industry's long-term financial future is rather uncertain.

The woos of the public transit industry had started in the United States well before the pandemic but became further aggravated as ridership dramatically declined during the pandemic. In Chap. 18, Alex Kurzhanskiy and Servet Lapardhaja focus on three transit operators in the Bay Area and describe their responses to the challenges generated by the pandemic. In particular, they discuss issues of service adjustments, fleet management, adjustment of performance metrics, and the ways that these transit agencies have operated paratransit in response to the pandemic.

The last two chapters of the book use scenario planning to offer policymakers a range of possible scenarios for recovery. As discussed in Chap. 5, the pandemic has affected transportation revenue needed to finance transit projects and operations of transit and highway systems. In Chap. 19, Asha Weinstein Agrawal, Hannah King, and Martin Wachs present six different revenue recovery scenarios for a range of possible futures for the State of California. The scenarios represent different combinations of future patterns in travel behavior and fleet composition, discussing high, medium, and low trajectories for each of five key variable inputs: (1) Annual state VMT; (2) light-duty vehicle fleet size; (3) light duty, zero-emission vehicle (ZEV) fleet size; (4) light-duty ZEV fleet values; and (5) Diesel share of the heavy-duty flee. Depending on the scenario, different transportation revenues can be accrued by 2040. Nevertheless, the authors note that, over the long term, structural factors other than the pandemic will have far greater impacts on revenue.

In Chap. 20, Susan Shaheen and Stephen Wong ponder ways that public transit and shared mobility—two industries that were hit hard by the pandemic—can recover. They relate findings from a scenario planning exercise with 36 U.S. transportation experts on ways that these industries can initiate recovery and eventually develop a more "resilient, socially equitable, and environmentally friendly transportation future." They discuss a series of short- and long-term actions, interventions, and policies that transit operators can follow in the areas of innovation and technology, planning and operations, customer focus, and workforce development. They also articulate broader policy strategies for both the public transit and shared mobility sectors in ways that they align with larger social goals (i.e., sustainability, resilience, etc.) and stabilize their funding streams.

Collectively, this book teases out the pandemic's impacts on mobility, accessibility, and transportation in California, other U.S. states, and some other countries. The concluding chapter underlines the book's major findings, summarizes common themes, and offers the editors' reflections on the lessons learned from the pandemic. As devastating as the pandemic has been for human life, it has also triggered responses, adaptability, and adjustments to human behavior. Some travel behavior adjustments have even had positive outcomes for the environment and transit safety. The challenges for scholars and policymakers in the years to come will be to develop policies and strategies to maintain the positives, correct the negatives, and do so in ways that are equitable and sustainable for society.

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