Evaluating public transit agency responses to the Covid-19 pandemic in seven U.S. regions

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A B S T R A C T

The Covid-19 pandemic's impacts on public transit will be felt for years, if not longer. In a few short weeks in 2020, the nature of day-to-day travel shifted around the world. Many of those who were able to stay at home did so while a large majority of those who needed to continue traveling moved away from public transit if they had alternatives available. For their part, public transit agencies responded with rapid service adjustments during March 2020, making varying efforts to communicate with riders and the public during this time so that users could understand how service was changing and how it would affect them. The impacts of the pandemic were dramatic—public transit ridership dropped by nearly 80% in April 2020 across the United States as the unemployment rate reached 14%—worse than any month during the Great Recession. But agency responses were nonuniform. In this paper, we characterize how seven public transit operators in the United States—those responsible for 55% of all unlinked trips in 2019—adapted service during the pandemic using quantitative performance information and a review of agency press releases. We also assess impacts on riders for whom public transit is essential. We find that pandemic-era changes largely did not change existing disparities between groups, suggesting that baseline inequities did not worsen as overall service levels fell. Understanding transit agency behaviors using different data sources is a first step towards linking agency responses with outcomes. This type of analysis that blends quantitative performance analysis with qualitative data can also provide insight into how agencies can adapt to future crises.

1. Introduction

The impacts of the Covid-19 pandemic on public transit will likely be felt for years to come. At the outset, mode choices changed dramatically, as a large majority of those who needed to continue traveling shifted away from public transit if they had resources and travel alternatives available, including vehicle access or telecommuting ability (He et al., 2022; Hu and Chen, 2021; Liu et al., 2020; Palm et al., 2021; Parker et al., 2021; Paul and Taylor, 2022). Reduced ridership then resulted in service reductions. In April 2020, 74% of U.S. agencies anticipated cutting services in response to lockdowns and closures (APTA, 2020, p. 19). A January 2021 survey of American Public Transportation Association members showed that 65% of surveyed transit agencies had already cut service temporarily due to revenue shortfalls, and 38% of agencies stated that they would cut service in the future to ease fiscal

pressures (APTA, 2021).

At the onset of the pandemic, it quickly became clear that those still using public transit were largely essential workers and their racial, ethnic, and income composition reflected what we know from decades of research on public transit riders—people of color were over-represented, as were non-English speakers and low-income people (Ahangari et al., 2020; Hu and Chen, 2021; Transit, 2020). These ridership patterns highlighted public transit as a critical community lifeline maintaining connections to work, healthy food, medical care, and other destinations.

These connections were strained as agencies made service cuts to contend with falling fare revenue but also to reconcile the competing objectives of viral exposure mitigation and ridership. Many agencies eliminated fare collection to minimize rider-operator interactions and enforced social-distancing rules that effectively reduced vehicle

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capacity. These measures affected levels of service; overall ridership plummeted, which led to further service reductions. But even within this general pattern, individual agencies responded differently, leading to different outcomes.

Understanding how and why agencies responded to the pandemic can inform responses to future crises. But little systematic information is available about transit agency Covid-19 responses. Much of the existing literature focuses on mitigating viral spread rather than managing operational service changes. Accordingly, our key research questions are twofold: 1) how and why did agencies adjust service in response to the pandemic? and 2) to what extent did agencies seek to address the needs of communities known to disproportionately rely on public transit and how did service cuts affect those communities? The second question is crucial because public transit provides the vital link between people and opportunities, especially for those without access to a private vehicle. Understanding agency responses using different data sources is a first step towards linking agency responses with outcomes. Our work blends quantitative performance analysis with a synthesis of agency press releases during the pandemic. The results provide insights into how agencies can best respond to future crises.

We drew our cases from a larger project on public transit access changes during the Covid-19 pandemic sponsored by TransitCenter (Da Silva et al., 2022; Klumpenhouwer et al., 2021). That work focused on public transit service in seven regions (defined by their metropolitan statistical areas), whose principal cities are Boston, Chicago, Los Angeles, New York, Philadelphia, San Francisco-Oakland, and Washington D.C. In this paper, we narrow the scope further to better match operational changes with agency responses by focusing only on the largest public transit operators in each of the principal cities listed (in San Francisco-Oakland, we use San Francisco). As of 2019, these seven operators together accounted for approximately 55% of total annual unlinked trips taken in the United States (American Public Transportation Association, 2021). When considering how transit riders were affected by agency pandemic responses, examining these seven will tell us about the experiences of people using public transit in the largest markets in the country. Although our results represent the majority of transit trips in the US, they should not be taken to represent the remaining 45% of trips, which are scattered across hundreds of smaller agencies.

The remainder of the paper is structured as follows. The literature review combines insights from mobility justice, transit rider scholarship, and agency guidance to identify a gap in transit agencies' strategies for pivoting during a pandemic, namely that existing recommendations focus on viral mitigation while providing little guidance on operational responses. A lack of guidance leaves open the possibility that providing quality service for those who need it most will be given short shrift in the midst of rapid service changes. We evaluate agency responses to the pandemic using quantitative public transit performance measures combined with synthesizing agency statements made in press releases. We find that, in general, existing differences in transit service provided between groups persist during pandemic-era service changes, meaning that groups more likely to rely on public transit were not disproportionately disadvantaged, but the magnitude of the service reductions incurred would have severely affected public transit's utility during the period under study.

2. Literature review

The term *transportation disadvantage* is used to describe conditions in which specific people, the groups to which they belong, and particular locations lack access to the transportation resources they need to lead a meaningful, dignified, and fulfilling life (Allen and Farber, 2019; Currie et al., 2009; Lucas, 2012). Access is properly understood broadly. It encompasses characteristics of available transportation resources, land uses, and individual socioeconomic characteristics (Karner et al., 2022). Together these characteristics determine how easily people can reach

opportunities from a given location (Geurs and van Wee, 2004; Martens et al., 2012). Two neighbors identical in all respects except that one of them is a wheelchair user will have dramatically different access experiences.

Transportation equity, transportation justice, and mobility justice are three terms that all take a normative perspective: transportation disadvantages must be mitigated, especially when they come about as the result of individual constraints rather than choices freely made (Karner et al., 2020). The three terms differ in terms of their approaches towards problem assessment and mitigation as well as the underlying theory of and approaches to achieving justice they embody. Accordingly, their recommended approaches for addressing the fundamental problem of transportation disadvantage differ substantially (e.g., Enright, 2019; Verlinghieri and Schwanen, 2020).

But in all three, public transit looms large. Prior work on transit riders has demonstrated that certain riders are essential in a double sense—they rely heavily on public transit to meet their daily needs and public transit agencies rely on them to provide a steady source of fare revenue as well as a *raison d'être* for the service (He et al., 2022; Taylor and Morris, 2015). In part because of transit's essential nature for these riders, they demand fundamentally different service from those who primarily or only use transit to commute (Farber et al., 2016; e.g., Grengs, 2002; Mann, 2004; Marcantonio and Mayer, 2010). Prior disputes between riders and agencies have centered on these critical questions of precisely whom public transit is for and the type of cities that will be created if certain infrastructure developments are pursued. Specifically, agencies often prioritize broad regional benefits, 9–5 commuters, airport travelers, and tourists over those who rely on public transit to meet a wide range of daily needs (Attoh, 2019; Enright, 2019; Golub et al., 2013; Grengs, 2002).

Public transit service changes have a profound effect on a rider's daily life. The onset of the Covid-19 pandemic in early 2020 engendered the single largest simultaneous national drop in service to date. While many workers were able to quickly shift to remote work, essential workers and others had to report in person throughout the lockdowns or after initial lockdowns waned (Liu et al., 2020). Available evidence suggests that low-wage workers, women, and people of color were more likely to remain on transit (He et al., 2022; Hu and Chen, 2021; Liu et al., 2020; Palm et al., 2021; Parker et al., 2021; Paul and Taylor, 2022) and faced greater transportation challenges as transit service became less desirable (He et al., 2022; Palm et al., 2021). These groups overlap with those known to rely heavily on public transit to meet daily needs. And if history is a guide, agencies might give the needs of these users short shrift when making service changes.

Despite knowledge that public transit is essential for some workers, especially during profound economic disruptions such as that brought on by the pandemic, transit agencies have surprisingly little guidance to follow related to short-term major service changes and which routes and riders to prioritize. Pre-existing guidelines were in place to help agencies plan for and respond to pandemics, but it is unclear the degree to which these guidelines were heeded or helpful. For example, the U.S. Department of Homeland Security (DHS) authored planning guidelines for responding to an influenza pandemic in 2008 (US Department of Homeland Security, 2008). In terms of service changes, they recommend agencies "identify and assess essential services, functions, and processes," with the aim of prioritizing such services based on their value to customers and the community. They include considerations such as how ridership demand might shift away from transit modes, how ridership would be affected by non-essential business closures, and how non-essential services can be rerouted to support essential ones.

In 2014, the National Cooperative Highway Research Program (NCHRP) released "A Guide for Public Transportation Pandemic Planning and Response" (National Academies of Sciences, Engineering, and Medicine, 2014). In terms of managing service, the document recommends pre-identifying essential services and refers to another NCHRP report, "Continuity of Operations Planning Guidelines for

Transportation Agencies," that outlines the process for making such identifications (National Academies of Sciences, Engineering, and Medicine, 2005).

Both the DHS and NCHRP guidelines recommend that agencies evaluate how to provide service in a pandemic, but they do not provide detailed recommendations for deciding on a route-by-route basis where and how much service might be needed. Despite the well-established premise that transit is a lifeline for a subset of riders, explicit discussions of equity are largely absent. The NCHRP guidelines mention in one location that agencies should consult "nonprofit stakeholders and rider representatives" when identifying essential functions (National Academies of Sciences, Engineering, and Medicine, 2014, p. 28).

Most work that specifically addresses transit agency responses during the Covid-19 pandemic focuses on mitigating viral spread as opposed to addressing how service should be changed in response. Shen et al. (2020) described a broad range of strategies based on responses in China including personnel training, facility planning, communication, and hygienic/cleaning procedures. One APTA report focused entirely on the issue of Covid-19 transmission while using public transit, including summaries of mitigation strategies undertaken in multiple locations around the world (Sam Schwartz Consulting and APTA, 2020). Baer and Larkin (2021) described similar responses specifically for U.S. transit agencies. Cohen (2020) presents a review of studies, simulations, and public health recommendations that can inform capacity limits for transit vehicles. A report by UITP highlights high-level agency responses from around the globe in managing transit service and demand as well as disinfection and containment strategies (Union Internationale des Transports Publics, n.d.).

Overall, the literature on transit agency responses during the Covid-19 pandemic has focused on mitigating viral transmission and sanitation rather than evaluating service changes and their implications for equity and justice. Existing analyses of agency responses are largely descriptive, describing best practices and success stories. Little to no analysis has focused on the question of how service should be altered to continue serving those essential riders who rely on public transit the most. In this work, we summarize public transit agency Covid responses for seven operators that account for 55% of boardings across the United States to understand why decisions were made and which riders they were likely to affect. Ultimately, the findings can inform responses to future crises so that essential transit riders can maintain access during major service changes.

3. Data and methods

We gathered quantitative data on public transit service delivered during 2020 as well as primary-source materials describing pandemic-related service changes. The quantitative data capturing transit service delivery were gathered from the TransitCenter Equity Dashboard (TED), which uses public transit routes and schedules released by transit agencies and publicly available demographic information to generate multiple estimates of transit system performance monthly from February 2020 through February 2021 in seven U.S. regions (Klumpenhouwer et al., 2021). Here, we used the TED's measure of "transit service intensity," which reports population-weighted average hourly trips in census block groups for a typical Wednesday. We compare these rates to a baseline level of pre-pandemic service (from February 2020) to estimate service reductions. The transit service intensity metric was developed for the TED to provide a relatively universal measure of the amount of service provided by transit agencies across regions without relying on land-use sensitive measures. In this way, it focuses on service delivered rather than the interaction between service and destinations, as in typical accessibility measures. The service intensity for each block group can be represented using equation (1),

$$\tau_i = |\{t | t \circ s \forall s \in S_i; t \in T\}| \qquad (1)$$

where τ_i is the transit service intensity for block group i on a typical Wednesday, t is a trip in the set of trips T offered by the agency such that the trip "serves" (°) at least one stop s for all stops S_i within a 200 m buffer around the polygon representing block group i. This approach avoids double counting trips that visit more than one stop in a block group's buffer. We subsequently calculated population-weighted means for all block groups that included at least one transit stop within the 200 m buffer using equation (2),

$$\overline{\tau}_{jk} = \frac{\sum_{i=1}^{N} \tau_i p_{ij}}{\sum_{i=1}^{N} p_{ij}} \qquad (2)$$

where $\overline{\tau}_{jk}$ is the population-weighted mean transit service intensity for population group j in region k on a typical Wednesday, p_{ij} is the population of group j in block group i, and N is the number of block groups in the region whose buffers include at least one transit stop.

The transit service intensity measure was chosen here as it is sensitive to two main ways in which transit agencies might adjust service: changing the number of trips (increasing or decreasing frequency) and changing the service period itself (increasing or decreasing span). While there are other commonly used supply-only measures such as revenue service hours, they are not spatially sensitive and do not allow for comparisons across population groups. The supply-only nature of the measure has its drawbacks: We do not account for demand at various times of day—trips added/cut at low-demand periods are arguably not as directly impactful to as many people, and so it is possible to achieve the same result on this metric using dramatically different temporal service configurations.

Using equations (1) and (2), we calculated performance for 14 dates spanning February 2020 to February 2021 at the seven public transit agencies listed in Table 1 responsible for the majority of unlinked passenger trips in the United States. In addition to examining overall service changes at each agency weighted by the total population, we looked within agencies at how transit service intensity changed for four racial/ethnic groups (Asian, Black, Latinx, and white) and one income-based category (households in poverty). The group comparisons are necessary to understand how pandemic-related service changes affected the service delivered to populations known to rely heavily on public transit.

We also reviewed transit agency press releases published over the same time period to glean information related to service changes and other operational initiatives that were clearly undertaken in response to the pandemic. This review involved searching agency websites for available press releases and reading all available for the time period under study (February 2020-February 2021). Our goal was to summarize and contextualize agency actions, not to extract or discuss themes from them or to implement any natural language processing approaches. We used the press releases to provide additional depth to the quantitative service provision data, providing insights into the motivation for agency actions. Examining TED data, which provides a comparable measure of transit service delivery, alongside agency press releases, which provide insights into agency strategies and reasoning, provides considerably more insight into pandemic policies and impacts than examining either data source in isolation.

Table 1
Regions and transit agencies included in this study.

Principal city	Operator considered for the purposes of this study
Boston, MA	Massachusetts Bay Transportation Authority (MBTA)
Chicago, IL	Chicago Transit Authority (CTA)
Los Angeles, CA	LA Metro
New York, NY	Metropolitan Transportation Authority (MTA)
Philadelphia, PA	Southeastern Pennsylvania Transportation Authority (SEPTA)
San Francisco, CA	San Francisco Municipal Transportation Agency (SFMTA)
Washington D.C.	Washington Metropolitan Area Transit Authority (WMATA)

4. Results and discussion

4.1. Overall service changes

All of the studied transit agencies faced similar trade-offs during the Covid-19 pandemic, with the need to absorb severe drops in ridership while maintaining some service for essential transit riders, implementing new sanitation protocols, enforcing social distancing, and dealing with staffing shortages due to illness and death. Fig. 1 shows that the operational response was not the same across each of the seven operators studied here. The figure shows population-weighted transit service intensity (Equation (2) over time for each agency, normalized to February 2020. Six of seven agencies studied (all except CTA in Chicago) substantially reduced service at the onset of the pandemic in early 2020. But they differed in the magnitude of cuts, modes affected, and length of time that the cuts persisted. New York's MTA is the only operator to have returned to full service by early 2021, though CTA and MBTA (Boston) were both operating at close to 95% of their February 2020 service at that time. SEPTA in Philadelphia performed similarly, reaching 92% of its pre-pandemic service intensity by February 2021. The other three regions were operating between 70 and 80% of their pre-pandemic service at that time. While WMATA (Washington D.C.) and Metro in Los Angeles were both trending downwards in the winter of 2020/21, the San Francisco Municipal Transportation Authority was on an upward trend.

MBTA's initial March 16, 2020 press release provides an indication of the ideas that guided their cuts (MBTA Press Office, 2020). It noted that they had developed criteria in consultation with public health professionals that would protect employees and customers. It also noted the need to maintain operations that support social distancing and maintain "workforce access for hospitals, as well as food distribution locations." The press release acknowledged that reduced ridership was driving reduced service. It is not clear how these three factors were balanced, but the intention seems to be that the MBTA would provide service at a level that supported social distancing based on the levels of ridership that they were observing.

Like other agencies, WMATA claimed that their service reductions were meant to protect customers and employees and facilitate sanitation efforts. Unlike other agencies, they noted that some of their employees were simply unavailable to work or work at normal amounts due to Covid safety or child care concerns (WMATA Press Office, 2020).

SEPTA took a relatively simple approach to service reductions compared to other agencies. On March 22, 2020 it switched entirely to a Saturday schedule (SEPTA press office, 2020a). Subsequent service reductions included the following statement: "SEPTA will continue to closely monitor all services to try to ensure that there is enough space on-board vehicles for customers to practice social distancing" (SEPTA press office, 2020b, 2020c). The agency also indicated that operators who no longer had routes to run would be reallocated to help maintain social distancing and cleaning efforts (SEPTA press office, 2020a). Whether this was a common practice is unknown, but it was not mentioned by other agencies. Overall SEPTA's process for making service reductions was initially vague; the agency simply cited a need to "maintain a safe environment for customers and employees" (SEPTA press office, 2020a).

On March 29, SEPTA reduced commuter rail service to an "essential service schedule" driven by extremely low ridership—a 94% drop compared to 70% on other modes (SEPTA press office, 2020c). They also noted that these service reductions facilitated additional cleaning time, but it is unclear how these two factors were balanced. The next day, SEPTA canceled overnight service, citing low ridership during these periods and a chance to give crews additional time to clean vehicles (SEPTA press office, 2020c). On April 9th, SEPTA further reduced service to what was dubbed a "Lifeline Service Schedule." This schedule shut down many lines and routes while maintaining those that provided service to "hospitals, grocery stores, and other life-sustaining services" (SEPTA press office, 2020d). Station access was limited by SEPTA police who would ensure customers were traveling for these essential purposes.

In describing its rationale for cuts, the MTA mentioned a need to provide access to essential services while protecting employees both on vehicles and in other facilities. Unlike other agencies, however, the MTA did not present service reductions as related to protecting customers. Indeed, reducing service is likely to result in greater crowding for constant travel demand. Additionally, the MTA was more forthright about the financial impacts that low ridership had on its operations along with the additional cost of cleaning, which they estimated to be about $300 million per year. MTA indicated that the cost of maintaining the system with severely depleted revenue on top of new costs meant that service reductions were necessary (MTA Headquarters, 2020).

Proactively, Los Angeles Metro formed a Contagious Virus Response Task Force on March 3, 2020 to coordinate between transit and public health agencies as well as to plan the agency's response to the pandemic (Chen, 2020). California's statewide stay-at-home order went into effect on March 19, 2020, and Metro responded the next day by running a
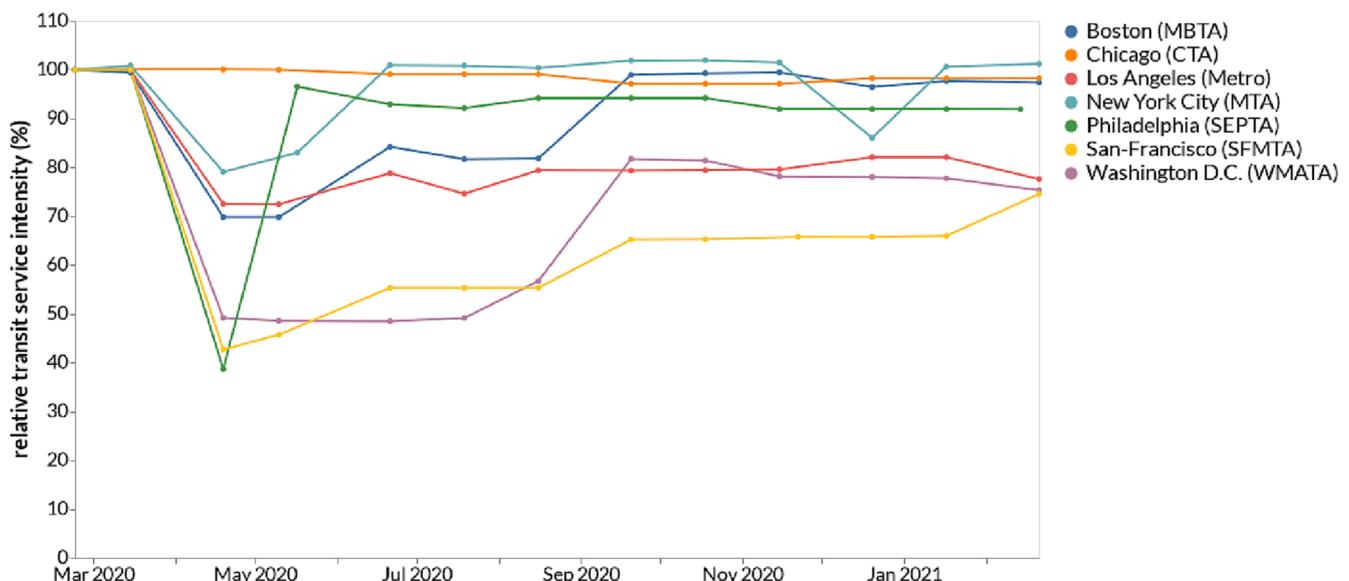

Fig. 1. Relative change in weekday transit service intensity during the Covid-19 pandemic for seven U.S. regions (service in February 2020 = 100%).

modified weekend schedule on its rail routes and reducing bus service by 15 to 20% (Chen, 2020). These initial reductions directly cite ridership drops as well as the reality of employees who needed to stay home due to vulnerability to infection or childcare. Like other agencies, they noted that they would be monitoring ridership to determine whether additional service was needed in certain areas (Hymon, 2020).

SFMTA initially reduced service on March 16, 2020, but on March 30, 2020 the agency decided to replace all rail service with buses (Barnett, 2020; Fowler, 2020). Stations were closed except for those that served transfers transferring from Bay Area Rapid Transit (BART). The shift to bus was motivated by a desire to redirect custodial services, minimize risk to station agents, and use the opportunity provided by low ridership to complete maintenance work on rail vehicles and infrastructure (Fowler, 2020). In general, SFMTA focused on providing service based on then-current ridership patterns and its "Equity Strategy"—a document that identified neighborhoods of high transit need based on concentrations of low-income households, people of color, low private vehicle ownership, public housing, seniors, and disabled people (Holland, 2020; SFMTA, 2018).

The rate at which agencies brought service back online varied substantially, with some rebounding within one or two months and others continuing with a reduced level of service throughout 2020. While it appears that rapid ridership decreases initially drove drops in the level of transit supplied, agencies with a lagging recovery adopted a "wait and see strategy." For example, WMATA planned to provide enough service ahead of ridership increases to relieve crowding, but not so much that they stretched their operating capacity (Finance and Capital Committee,

2020). SFMTA was similar in that they stated that their recovery would respond to increasing ridership gradually. At the same time, SFMTA had a particular focus on providing service to the essential transit riders who rely on the system. The agency used pre-existing equity plans that explicitly identified areas where likely transit-dependent populations live and aimed to provide service near those areas. According to their press releases, they also incorporated community engagement and feedback into their recovery process (Maguire, 2020).

LA Metro and SFMTA have also emphasized non-public transit solutions more than agencies whose services recovered more quickly. For example, SFMTA has been using private micromobility companies to "fill transportation gaps" during the pandemic and LA Metro's final recovery task force report similarly encourages expanding telework options, bike share programs, and micro-mobility partnerships (Dunn, 2020a, 2020b; Metro's Recovery Task Force, 2021).

5. Impacts on essential transit riders

While some agencies noted that they focused on providing access to essential destinations like grocery stores and medical facilities, this is plainly not enough—providing service to particular destinations does not necessarily connect the riders who depend on transit to those destinations. Agencies differed in how they understood essential riders and trips. Some, like SEPTA and MBTA, sought to maintain service for healthcare workers or to specific types of destinations, like grocery stores. Only one, SFMTA explicitly mentioned a focus on a broader set of essential riders when describing pandemic-related service
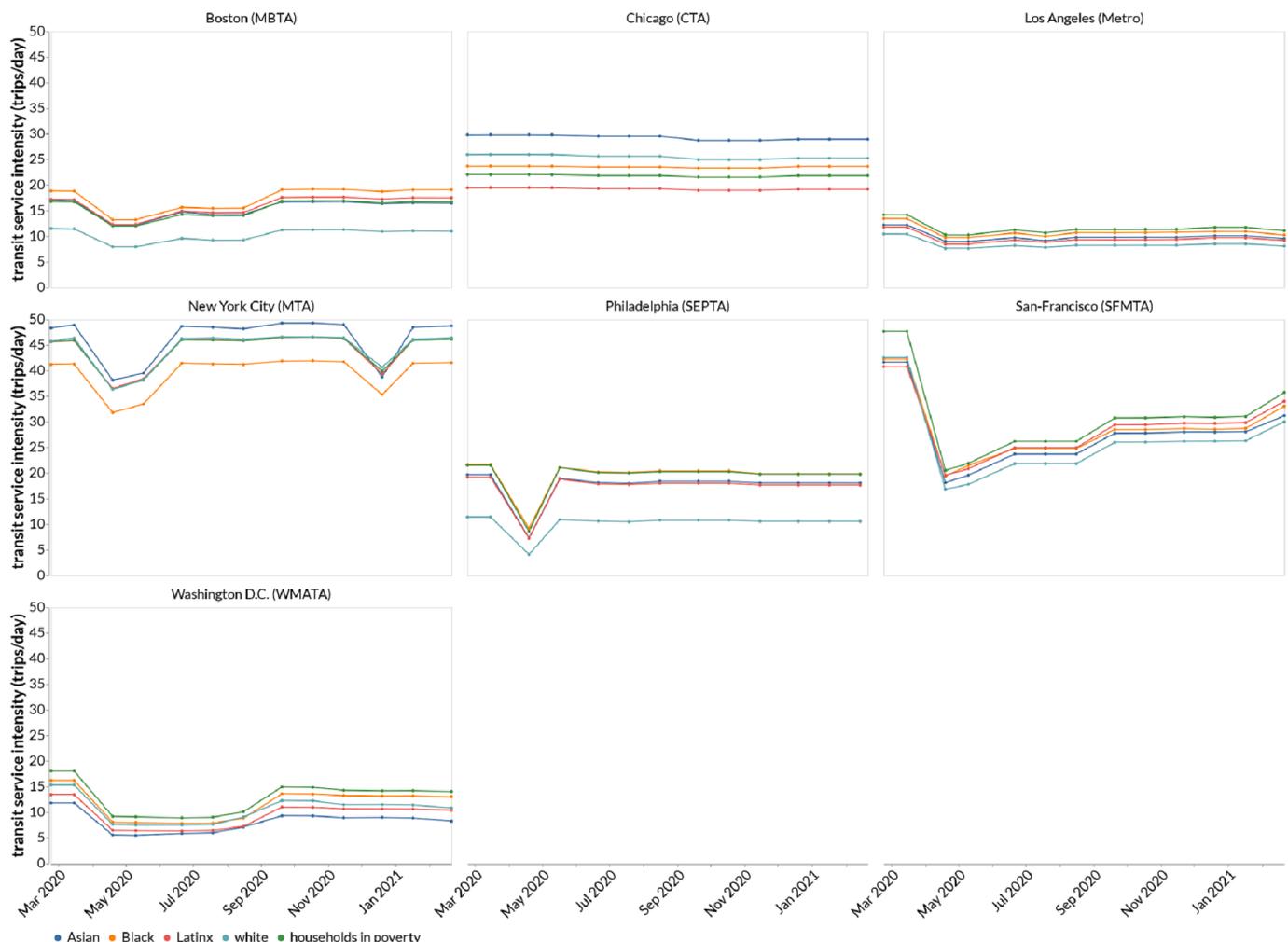
Fig. 2. Population-weighted transit service intensity at seven U.S. transit agencies for five demographic groups, February 2020-February 2021.

changes—those for whom transit is essential, rather than those who were deemed to be providing an essential societal service. While at least one agency (SFMTA) had an existing equity plan that helped maintain service for riders who rely on transit, many agencies adapted by adjusting service based on ridership. Nearly every agency mentioned this as part of their strategy, though few provided specific details.

In any case, it is difficult to identify how essential transit riders were affected by pandemic-era service changes from press releases alone. Accordingly, and to bring further specificity to the discussion, Fig. 2 shows change in transit service intensity across the entire period of study for five demographic groups, separately by each agency. It is possible that the implemented changes would have affected some groups more than others. Fig. 2 convincingly shows that almost all of the service changes had very similar effects on all demographic groups. With few exceptions, the relative position of the groups is unchanged throughout the entire period. The overall ordering of the groups and the gaps between groups are more notable and much more stable than the changes engendered by pandemic-era service cuts.

For example, there is very little difference in service intensity across groups in Los Angeles Metro's service area at any time. MTA and CTA both have substantial gaps in service provided to Black residents and Latinx residents, respectively, and these groups also experience the lowest service intensity overall. Again, these gaps do not worsen throughout the pandemic, but neither do they improve. On the other hand, MBTA, SEPTA, and SFMTA all show the lowest levels of service intensity for white residents, with relatively greater service provided to all other groups. There are modest changes in the relative gap between groups, for both SEPTA and MBTA, the gap initially shrinks—meaning that the relative gap between white residents and others gets smaller. But after the initial drop it returns to its pre-pandemic level. For the SFMTA, the relative gap simultaneously shrinks for households in poverty while it grows for white residents. The gap between white residents and other groups is maintained throughout the entire study period and is consistent with the agency's stated goals for their pandemic service adjustments.

One complication of the population-weighted transit service intensity measure used here is that only delivered service is under an agency's control. Residential populations shift over time, and ongoing patterns of residential segregation, gentrification, and displacement affect who chooses (or is able to) live in particular neighborhoods (Zuk et al., 2018). High-quality public transit is an amenity whose value gets capitalized into land prices, affecting housing costs and rents (e.g., Yang et al., 2020). White flight, subsequent disinvestment, and discriminatory lending dramatically shifted urban demographics in the United States throughout the latter half of the 20th century (Jackson, 1987; Kruse, 2007; Rothstein, 2017) and could account for some of the agency patterns where white residents have the lowest level of public transit service.

While transit service intensity offers some strengths, in that it does not depend upon land use, it also embodies limitations. It does not consider actual demand for public transit. Rather the metric shows the distribution of transit service throughout a population without incorporating knowledge on desired or realized travel behavior. Looking at public transit service in isolation can also present a distorted sense of service equity. Importantly, poor service everywhere for all groups is equitable but not useful. To truly understand whether public transit provides a useful service, relative or normative comparisons are necessary (Martens et al., 2022). As demonstrated by the TED, in each region, automobile access far exceeds that provided by public transit, raising questions about what level of adequate service should be provided during pandemic conditions. Additionally, measures of access that focus on the transportation system itself may fail to capture important components of people's experiences with the system and their realized access. For example, the increased police presence on SEPTA vehicles during the peak of the pandemic may have decreased access for those who were concerned about the risk of harassment or harm by law enforcement, although for others this increased police presence may have had the opposite effect.

6. Conclusions

Pandemic-era public transit cuts profoundly reshaped the service delivered in systems relied upon by the majority of transit riders in the United States. Many agencies revised service frequently during the initial months of the pandemic, sometimes day by day. The most common strategy involved implementing pre-existing weekend schedules, sometimes in concert with modifications to certain routes. Agencies also implemented service reductions rapidly without clear guidelines. Sometimes these had to be reversed or supplemented as in Boston and Washington, DC.

In making these initial changes, agencies had some existing guidance to follow, but the logic and reasoning underpinning that guidance often focused single mindedly on mitigating viral transmission rather than maintaining access for essential riders. In hindsight, this emphasis was misplaced, meaning that initial ideas about what factors should be driving operational decisions during a pandemic or other emergency might be incorrect. The emphasis on sanitation and social distancing, driven by the assumed initial dominance of fomite (surface) and droplet transmission, likely consumed more resources and resulted in less service while providing only questionable health benefits. For these major operators responsible for the majority of rides in the United States, maintaining the essential connectivity they provide was critical for keeping people connected to key destinations. Of course, the severely limited efficacy of sanitation and distancing measures could not have been known in advance, but these lessons must not be forgotten during the next pandemic.

Some agencies, including Los Angeles Metro and SFMTA, began to pursue alternatives to fixed-route transit during the pandemic. These policy shifts would not have been captured in our service intensity measures but may point towards a future for public transit systems that looks very different from the past. As of late 2022, U.S. agencies are being supported by federal largesse, but that support will likely expire within several years. Agencies that pivoted to provide less fixed-route service may ultimately prove to have a more robust business model than those that quickly restored pre-pandemic service levels. But delivering less fixed-route service to riders and relying more on alternative modes brings a host of other issues related to access, out-of-pocket costs, labor rights, and justice. These issues may ultimately have implications for overall public transit mode share. The long-term impacts of the Covid-19 pandemic and the sustainability of different operational strategies and responses will not be known for some time.

Relying on quantitative information and agency press releases embodies a number of limitations that must be mentioned. Importantly, the press releases do not give insight into the underlying institutional, governance, and administrative factors that drive agency decision-making. Future work could expand on that provided here to identify the key factors that led to more equitable outcomes and/or long-term system resilience. These might include the level of government responsible for the agency (e.g., city, special district, state), revenue sources and their relative importance (e.g., formula funds or fares), organizational structure (e.g., board composition and membership). The lessons learned from the Covid-19 pandemic will undoubtedly assist transit agencies as they prepare for future pandemic disruptions.

CRediT authorship contribution statement

Alex Karner: Conceptualization, Methodology, Software, Investigation, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition. **Seth LaRue:** Investigation, Writing – original draft. **Willem Klumpenhouwer:** Software, Writing – original draft, Writing – review & editing. **Dana Rowangould:** Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

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