Bus Operations of Three San Francisco Bay Area Transit Agencies during the First Year of the COVID-19 Pandemic

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Executive Summary

This report describes the results of monitoring three transit providers in the San Francisco Bay Area — Alameda-Contra Costa Transit District (AC Transit), Valley Transportation Authority (VTA), and Tri Delta Transit — during the first year of the COVID-19 pandemic (starting in March 2020 through March 2021). While we had initially hoped to report on the role of transit in the recovery phase this was not possible due to the continuing nature of the pandemic. Therefore this report is limited to how these agencies' operations were affected and their efforts to safely maintain some level of service.

In this report, we first introduce the monitored transit agencies. Second, we describe the agencies' response to COVID-19 based on our interviews with staff. Third, we discuss the geography and demographics of the areas serviced by the three agencies.

As in other regions across the nation, the COVID-19 lockdown declared by the Bay Area counties on March 16, 2020, resulted in severe losses in mass transit ridership. AC Transit and VTA ridership had fallen close to 90 percent by early April 2020, while Tri Delta Transit had suffered a ridership loss of almost 80 percent. All three providers initially stopped collecting fares to provide financial relief to riders. Then, throughout the remainder of 2020 and early 2021, ridership slowly climbed to less than 50 percent for AC Transit and VTA, and up to around 60 percent for Tri Delta Transit. The pace of this recovery was not steady as local ridership declines occurred during protests in June 2020, during fare reinstatements in autumn 2020, and during the second COVID wave in winter 2020-21.

People who stayed loyal to public transit came mostly from low-income areas with a high percentage of poor Latino, Black and Asian populations and undocumented immigrants. These people typically did not own a vehicle, but had to go to work because they were essential workers or simply could not afford staying jobless. In addition, AC Transit and VTA reported that during fare-free service periods, numerous unhoused individuals used their buses as shelters.

Agencies' response to the pandemic consisted of three parts: 1) maintaining the health and safety of their employees; 2) minimizing COVID risk for their riders by keeping buses clean and enabling social distancing through capping the number of passengers on buses; and 3) reducing service. By fall 2020, all three agencies started providing hand sanitizers and masks to passengers as well as cleaning their buses more than once a day. AC Transit and VTA cancelled or modified certain routes in addition to reducing bus service frequency. Tri Delta Transit reduced their bus frequency to tailor their schedules to those of BART. AC Transit adjusted its service on a monthly basis; VTA week by week; and Tri Delta Transit quarterly.

All three agencies reported a pass-up problem when bus drivers passed stops with waiting passengers because their buses were already full. This happened on certain routes during particular times of day due to reduced service. AC Transit and Tri Delta solved this problem in real time by dispatching extra buses as needed on routes with reported pass-ups. VTA revised its schedule weekly in response to reported pass-ups.

During the pandemic some transit agencies considered adopting flex routes.[1] All three agencies are skeptical about the concept, but AC Transit was the only one to have experimented with it prior to the pandemic. However, according to AC Transit, flex routing had proved to be ineffective, and was not employed during the pandemic.

Despite the dramatic ridership loss, public transit proved to be an indispensable means of transportation for those who had to get to work or needed to access essential services but could not afford private alternatives. Thus, public transit served as a necessary buttress for the economy in a critical time. Even under normal conditions public transit cannot be supported from farebox revenues alone. Now, with ridership still well below normal, transit service is even more heavily dependent on public subsidies to remain a viable alternative as the recovery moves forward. To provide any significant source of revenue, ridership will need to grow much faster than is currently happening. At the present time, it is unclear what impact the delta and omicron variants will have on what is still a weak transit recovery.

[1] A flex route allows for deviations without creating excessive delays for other riders on the bus.

Introduction

COVID-19 and the associated local- and state-level restrictions, have radically changed people's behavior and affected public transit. At the start of the pandemic. most commuters abandoned public transit entirely. Many began working from home; some began driving to avoid contact with others; while others lost their jobs (Abouk and Heydari 2021). Those who have remained loyal to public transit during the pandemic have primarily been frontline workers (e.g., nurses, grocery store clerks, warehouse workers) who could not work from home or commute by car (Hu and Chen 2021).

Several studies have investigated the impact of COVID-19 on public transit. A study from Wilbur et al. (2020) found that ridership dropped by 66.9 percent at its peak in Nashville, but by July 1, 2020 ridership had stabilized at a 48.4 percent reduction compared to 2019 baselines. The authors also found that the most significant decline occurred during morning and evening commute times, and that high-income areas of Nashville saw a decrease in ridership of more than 19 percent compared to low-income areas. Another study conducted by Fissinger (2020) in Chicago also found that higher levels of ridership were maintained in lower-income parts of the city. On top of that, while there was more ridership percentage growth in the high-income areas between the early stages of the pandemic and the summer, when looking at losses compared to pre-pandemic levels, ridership in low-income areas still remained much closer to pre-pandemic levels than high-income areas. These findings are supported by other studies (Bliss, Lin, and Patino, M. 2020; Brough, Freedman, and Phillips 2020; Sy et al. 2020), which found that lower-income, less-educated, and non-white workforces experienced the least amount of change in transit usage.

A study by Ahangari et al. (2020) created a model to evaluate the factors affecting ridership during the early pandemic in ten cities, concluding that poverty and education levels, citizenship, vehicle ownership and employment status were the major influencing factors. Not surprisingly, communities with lower poverty and higher education levels, predominantly U.S. citizenship, higher vehicle ownership and lower unemployment saw higher reductions in bus ridership.

Another study, which examined 113 transit systems across the U.S. found that the average ridership reduction was about 73 percent (Liu, Miller, and Scheff 2020). However, there were clear geographic differences, with cities in the Deep South and Midwest presenting a smaller decline in public transit demand, while high tech locations, such as the San Francisco Bay Area, and university cities, such as Ithaca, Ann Arbor, and Madison, generally experiencing a larger decline in public transit demand. The study showed that greater decreases in transit demand were associated with a higher percentage of people in non-physical occupations. Additionally, higher percentages of older people and African Americans in communities contributed to higher levels of continued transit use during the onset of the pandemic (Liu, Miller, and Scheff 2020).

But how have transit providers reacted to the new conditions brought about by the pandemic? This report describes the results of monitoring three transit providers in the San Francisco Bay Area — AC

Transit, VTA and Tri Delta Transit — during the first year of the COVID-19 pandemic, starting in March 2020 through March 2021. While we had initially hoped to report on the role of transit in the recovery phase this was not possible due to the continuing nature of the pandemic. Therefore this report is limited to how these agencies' operations were affected and their efforts to safely maintain some level of service given the slow pace of reopening. Table 1 summarizes common original expectations at the start of the pandemic and what actually happened.

Table 1. Expectations and Reality.

Early Expectations	Actual Events
Removal of COVID-19 restrictions by June 2020.	Removal of restrictions happened partially; theaters, concert halls and churches remained closed.
Reopening of small businesses during the summer and early fall 2020.	Small business reopening happened to a rather limited extent; some small businesses, such as hair salons, reopened briefly, but then closed again in anticipation of the second COVID wave.
School and university students return to classes in the fall.	Schools and universities decided to stay in online mode.
Organizations resume business as usual during fall 2020, and by the end of the year society returns to its pre-COVID normal.	Some non-essential workers returned back to their offices following safety guidelines that prevented crowding. But at the end of 2020, a new lockdown was imposed due to the second COVID wave.
As the economy and society returns to the pre-COVID mode, city streets and highways start experiencing higher than usual vehicular and bicycle demand at the expense of public transit ridership due to "coronaphobia."	This did not happen; transit ridership remained low; vehicular traffic in fall 2020 returned almost to pre-COVID levels, but did not exceed them.
Plethora of opportunities for bus transit agencies to try out on-demand dynamic services to attract more travelers.	Transit agencies dismissed the whole idea of on-demand dynamic routes as nonviable.

The rest of the report is organized as follows: First, we introduce the monitored transit agencies; second, we describe the agencies' response to COVID-19 based on our interviews with their staff; and third, we discuss the geography and demographics of the areas serviced by the three agencies.

Profiles of Monitored Transit Agencies

We monitored three San Francisco Bay Area transit agencies: two large – AC Transit and VTA; and one small – Tri Delta Transit. These three agencies are different in size, structure and, to a large extent, types of travelers they serve.

AC Transit (Alameda-Contra Costa Transit District) is a large Oakland-based public transit agency governed by a directly-elected board and serves the western portions of Alameda and Contra Costa counties, which include many colleges and universities. It operates as a special district under California law, and is not a part of or under the control of Alameda or Contra Costa counties or any local jurisdictions. It serves a diverse population in terms of income, employment status, race and citizenship. Its area of operation is divided into five wards and encompasses the following cities and unincorporated areas:

> Ward 1 – Berkeley, Albany, Richmond, San Pablo, El Cerrito, Kensington, El Sobrante and East Richmond Heights;
>
> Ward 2 – Southern part of Berkeley, Emeryville, Oakland and Piedmont;
>
> Ward 3 – Alameda, Southern part of Oakland, San Leandro;
>
> Ward 4 – Hayward, Southeastern part of San Leandro, Ashland, Castro Valley, Cherryland, Fairview and San Lorenzo; and
>
> Ward 5 – Western part of Hayward, Newark and Fremont.

In addition, the district's bus lines serve parts of other East Bay communities, including Milpitas, Pinole, and Union City. The district also operates transbay routes across San Francisco Bay to San Francisco and selected areas in San Mateo and Santa Clara counties. AC Transit serves many colleges and universities including the University of California, Berkeley; Stanford University; California State University, East Bay; Chabot College; Holy Names University; Peralta Colleges (Laney College, College of Alameda, Berkeley City College, and Merritt College), Contra Costa College; Ohlone College; Northwestern Polytechnic University; and Mills College.. Much of its ridership is concentrated on a few heavily trafficked local routes connecting colleges and shopping malls with regional train services, primarily BART (Bay Area Rapid Transit), ACE (Altamont Corridor Express), and Amtrak.

The Santa Clara **Valley Transportation Authority (VTA)** is another a large transit agency headquartered in San Jose and governed by a board appointed from Santa Clara County city council members and county supervisors. The agency responsible for public transit services, congestion management, specific highway improvement projects, and countywide transportation planning. Operating three light rail lines and 50 bus lines, it serves the core city of San Jose (where VTA is based and headquartered), with service to other municipalities. Most of VTA's ridership are employed in the technology, healthcare, government, education and construction/utilities sectors.

Operating three light rail lines serving Campbell, Milpitas, Mountain View, San Jose, Santa Clara and Sunnyvale and fifty bus lines, with service to the municipalities of Campbell, Cupertino, Gilroy, Los Altos, Los Altos Hills, Los Gatos, Milpitas, Monte Sereno, Morgan Hill, Mountain View, Palo Alto, Santa Clara, Saratoga and Sunnyvale. Only Express bus service is provided to nearby Fremont where it connects with BART. VTA partners with Highway 17 Express to provide service to Santa Cruz and partners with Dumbarton Express to provide transbay service between Union City and Stanford University. Many VTA bus routes connect to its light rail service, and Caltrain stations. In addition, VTA operates a special service for Levi's Stadium events, school trip services, and free shuttle routes connecting to ACE commuter rail services. VTA's longest and most-used bus route is the 22, which connects VTA's Eastridge Transit Center in East San Jose with the Caltrain station in Palo Alto, which serves as a transfer point for SamTrans buses from San Mateo County.. (VTA 2020).

Tri Delta Transit is a small suburban agency with just over 60 buses operating on 15 routes on weekdays and on five routes on weekends, providing bus service for the eastern area of Contra Costa County. Its bus routes connect to BART at the Pittsburg/Bay Point and Concord stations. They also connect with County Connection, WestCAT and Delta Breeze bus services at shared bus stops, as well as with Amtrak. A large portion of the Tri Delta ridership are blue-collar workers.

Tri Delta a joint powers agency of the governments of Pittsburg, Antioch, Oakley, Brentwood, and Contra Costa County It is governed by a board appointed from city and county representatives.

How Bay Area Transit Agencies Responded to COVID-19

With the COVID-19 lockdown declared by Bay Area counties on March 16, 2020, AC Transit and VTA ridership fell almost 90 percent by early April 2029-0, and Tri Delta Transit suffered almost an 80 percent ridership loss. The subsequent recovery has been slow, and a year later ridership was still well below pre-COVID levels.

For reference, Figure 1 presents a timeline of ridership, spending, COVID spread and vehicle traffic on Bay Area bridges and events from March 2020 to March 2021 compared with the same data from a year before. Here we have ridership data by agency represented by the number of trips per day – these data come from the automatic passenger counts (APC) provided by the agencies; estimated weekly spending and the number of registered COVID cases in the operation areas of the three agencies provided by Replica Trends for 2019-2021; and traffic volumes on three bridges – Bay Bridge, San Mateo Bridge and Benicia-Martinez Bridge – coming from PeMS. Where applicable, data for the pre-COVID year are displayed using dashed lines.

Here we observe a steady growth of transit ridership after the initial decline in late March of 2020. June 2020 protests, autumn fare reinstatements by transit agencies and winter 2020-21 second wave of COVID turned out to be local events not affecting the ridership growth trend. The growth rate, however, remained rather slow. In comparison, the recovery of spending and vehicular traffic at major bridges of the Bay Area was going much faster. By March 2021, traffic at San Mateo and Benicia-Martinez Bridges practically returned to the pre-COVID levels.

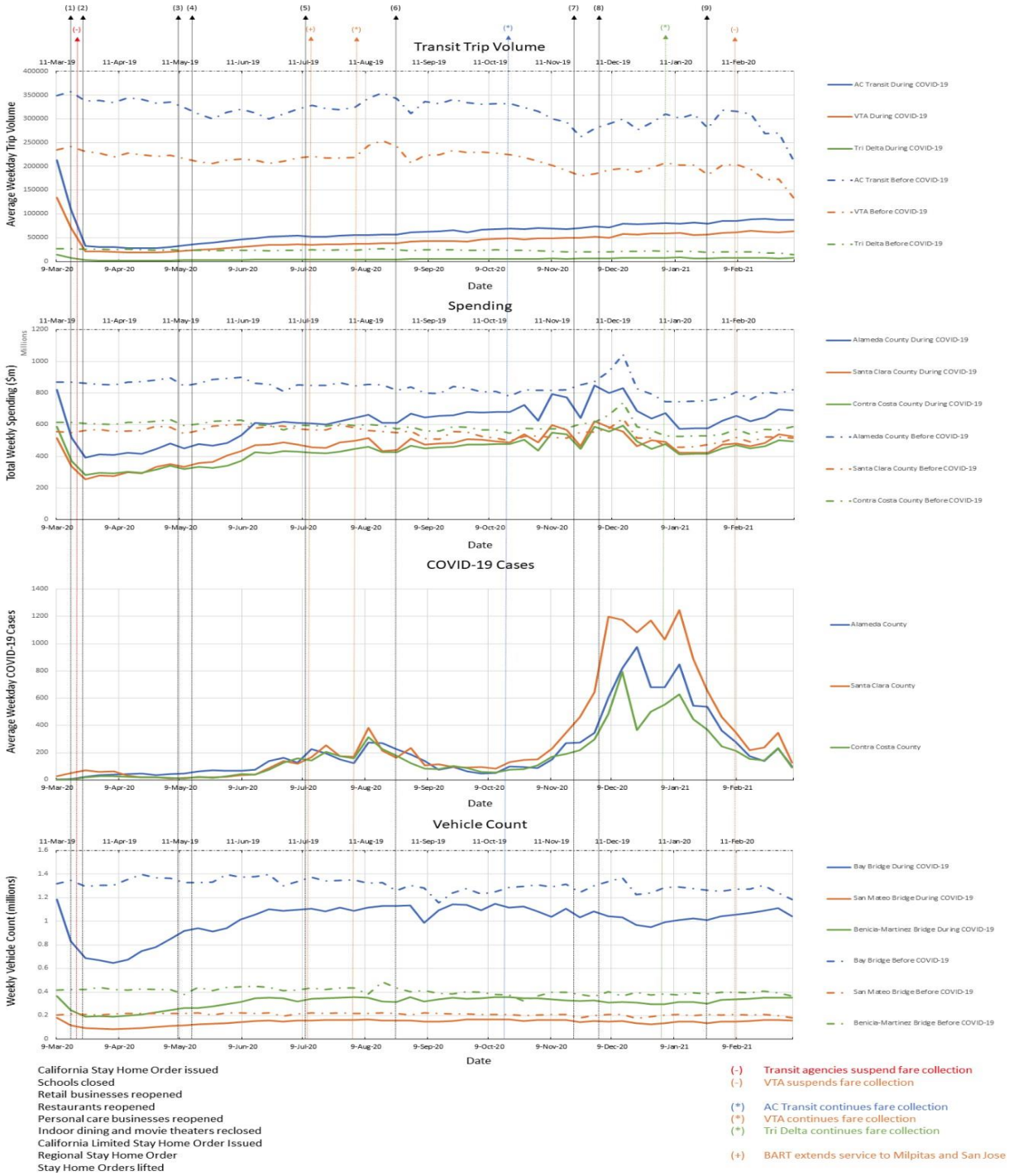

Figure 1. Timeline of ridership, spending, COVID cases, vehicle traffic on Bay Area bridges and events from March 2020 to March 2021 compared with the same data from a year before.

This section presents the findings from interviews with staff from the three transit agencies (AC Transit, VTA, and Tri-Delta Transit). In the period from March to June 2020, agencies reviewed their ongoing and planned projects. Those projects not directly helping to address the COVID-19 situation were put on hold.

Commonly Identified Priorities

In response to COVID, the agencies formed a common task force that identified the priorities, which the agencies accepted and proceeded with their implementation:

1. Preventing the spread of coronavirus among agencies' employees. Regular COVID tests for employees and the installation of contactless thermometers to prevent employees with fever from entering crowded areas were discussed.

2. Protecting bus drivers from infected passengers. To achieve this, rear-door boarding was suggested as well as installation of plastic shields separating the driver from passengers.

3. Keeping passengers safe through the following means:
   a. Reducing the passenger capacity limit to 12 for single-car buses — to enable 6-feet social distancing. Masks for passengers became mandatory by the end of summer.
   b. Keeping buses clean through frequent disinfection. The discussion was centered around hiring more janitorial services and exploring the use of ultraviolet lamps.
   c. Implementation of contactless payments. While this remains on the agenda all the agencies went into the fare-free mode in the second half of March 2020.

4. Keeping up the funding and maintaining the workforce. Neither of the three agencies downsized their workforce, although services were reduced considerably.

After the initial shock, the transit agencies found their new equilibria concerning service, fleet management, performance evaluation and paratransit service. The agencies' changes in operations are described next.

COVID-19 Service Adjustments

AC Transit canceled all transbay, school-bus and flex (otherwise known as dynamic) routes,[2] and adopted a weekend schedule for weekdays. In general, all the processes for route adjustments remained the same as before COVID: they are made four times a year — in December, March, June, and August — while minor schedule adjustments, small route changes, and bus stop fixes are addressed on a monthly basis. As mentioned above, the AC Transit bus network is divided into five wards, and service is managed by ward.

[2] A flex route allows for deviations without creating excessive delays for other riders on the bus.

In contrast to AC Transit, VTA is managed as one single unit. Pre-COVID, annual service changes were scheduled at the beginning of each year. At the start of the pandemic, service was adjusted on a weekly basis. Notably, all school-bus, express and rapid routes were suspended. Light rail service was also initially canceled, but reinstated in April 2020. Some routes were shortened; for example, areas around Santa Clara University and San José State University did not need service as these schools went into lockdown. The Sunday schedule was used as the basis for daily operations. Weekday additions to this base included routes going to hospitals.

Tri Delta Transit did not change the structure of its routes. Changes were limited to reducing weekday schedules (intervals between buses became twice as long as before COVID) and replacing Saturday and Sunday schedules with just one Sunday schedule. Following its mission of connecting people to BART, Tri Delta Transit tailored its schedules to changes in those of BART.

All three agencies stopped fare collection beginning in April 2020. VTA resumed fare collection and front-door boarding on August 1, AC Transit on October 19 of 2020, and Tri Delta in January 2021. VTA went back into fare-free and rear-door boarding mode on February 8, 2021, a month after new COVID cases peaked in Santa Clara County. This was done as part of a measure to reduce COVID spread between VTA employees. Fare collection was resumed in April 2021.

All three agencies admitted that available funding defined their service adjustments. They all are funded with a mix of federal, state, and local government subsidies, as well as passenger fares. Passenger fares were not a decisive factor during COVID even though AC Transit and VTA were losing over a million dollars per week in uncollected fares as they were provided with additional funding by the Metropolitan Transportation Commission from the federal Coronavirus Aid, Relief, and Economic Security (CARES) Act.

Fleet management

AC Transit uses different kinds of buses for different services — local, transbay, express, and school. Only local and express buses continued running during COVID. About 75 percent of these buses are equipped with automatic passenger counters (APC) that are used to assess ridership. Within a given service, the agency rotates its fleet to maximize ridership coverage in its service area. About 80 percent of the fleet was in service under COVID bringing the APC coverage rate up to 95 percent.

About 85 percent of VTA buses and all its trains are equipped with APC. Its fleet rotation before COVID was based on maximizing the APC coverage rate and the requirement of having long (double-car) buses on certain routes with high ridership. Given a 56 percent service reduction under COVID, all buses were equipped with APC, so rotation was governed only by the bus size requirement.

Tri Delta Transit buses are also equipped with APC. Except for two routes where electric buses operate, elsewhere the fleet is assigned randomly. The two routes with electric buses are determined by the Low Carbon Emissions Funding Program to connect certain communities of concern to BART. About 70 percent of the Tri Delta fleet was active during COVID.

Neither of the three agencies to date processes APC data in real time. Passenger counts are downloaded from buses at the end of the day as they return to the garage. Then, it takes 3-5 days for data to be processed, cleaned and entered into each agency's system.

Performance Metrics and Their Effect on Service Adjustment

When a bus is full, and no one wants to exit, a bus driver will typically keep going without stopping for passengers waiting at a stop. This situation is called a "pass-up" and is reported by the bus driver. Since the breakout of COVID-19, all the three agencies have experienced pass-ups due to reduced number of buses. The number of pass-ups has become an additional performance metric for AC Transit and VTA.

The main performance metrics for AC Transit are: being on time and ridership numbers on most routes. Ironically, being on time during COVID often meant that bus drivers had to stop mid-route and wait to avoid arriving too early at their destination, because the streets were too empty. Route productivity is estimated based on the number of boardings per revenue hour. The guiding principle for service adjustment is to keep up or improve high-productivity routes (generally, these are trunk routes running along major arterials), and reduce, modify or cancel underperforming routes (generally, these are peripheral routes). These metrics are examined on a monthly basis and decisions are made about service adjustments. It is not always easy to cancel an underperforming route. AC Transit constituents often pressure the Board to keep up certain routes, even when there are very few passengers.

As mentioned, prior to the pandemic, AC Transit operated two flex routes. The route that these flex routes replaced carried on average 8-10 passengers per revenue hour and the flex routes' ridership was only 3-4 passengers per revenue hour, which was considered too low. These flex routes were canceled during COVID and are unlikely to be resumed.

Once a week, AC Transit evaluates the number and location of pass-ups. For routes experiencing frequent pass-ups, standby buses are assigned as needed to pick up those passengers left unserved. These standby buses are managed from the Operations Control Center, which provides a real time response.

VTA uses boardings per hour as a primary performance metric for route adjustment. During the study year, the number of pass-ups were used to adjust the schedule in addition to the boardings per hour. In general, VTA concentrated on trunk routes and tried to maintain high-frequency service there, whereas peripheral routes with low ridership were being canceled. Ridership performance Is not a sole criterion for route modification though. For example, in Morgan Hill a low-performing single route, was not cancelled so as to keep the community connected. Metrics such as equity do not play an explicit role in VTA decisions about their service, however.

Tri Delta Transit monitored ridership (boardings per revenue hour) and on time performance. However, these metrics were not used as triggers for service adjustments. Routes were set and did not change very often. Schedules could be modified, but those modifications were dictated by BART schedule

changes. Pass-ups generally occurred only on selected routes during certain hours of the day, at which time s, the agency was ready to dispatch extra buses as needed.

VTA and Tri Delta Transit did not consider switching to flex routes given their ridership patterns and operational structure, believing flex routes would not add value.

All three agencies expressed a desire to have APC data available in real time for the purpose of reporting bus overcrowding to end users through trip planners, such as a transit app. Presently, when this information is displayed in a trip planner, it comes from a ridership estimation based on historical passenger counts.

Protests and riots that took place in early June 2020 had a negative impact on AC Transit ridership and operation in the Oakland area (Ward 2). Detours were established in downtown Oakland. A large number of pass-ups were recorded because buses would not stop when it was not considered safe. Ridership during the first half of June dropped across the board, but especially on the Oakland–San Leandro route. VTA observed a mild drop in ridership during the period of protests, but this did not affect its operation. Tri Delta Transit operations were not disrupted by protests either.

Paratransit

In pre-COVID days the demand for paratransit services was higher than the agencies were able to provide, and it was handled on the first-come-first-serve basis. During the COVID period the demand was dramatically reduced.

AC Transit partners with BART to provide paratransit service. AC Transit's East Bay Paratransit is the largest operation in the San Francisco Bay Area. It is demand-based and is operated through contracted services. Normally they run 2500 trips per day, which during COVID dropped to 450 trips per day. Since it is a contracted service, the reduction did not directly affect AC Transit operations.

VTA acknowledged that paratransit service suffered during COVID due to low demand, however it did not indicate that there were any service disruptions or workforce downsizing.

Tri Delta Transit started as a paratransit provider, only later becoming a general-purpose transit agency. During COVID, paratransit demand went down, but on par with the rest of the service so no special measures were required.

Analysis of Changes in Ridership

In our study, we looked at the geography and demographics of transit users during COVID. Figure 2 displays changes in the distribution of transit use from April 2019, a year before COVID, to April 2020, when the whole Bay Area was in lockdown, to March 2021, our last month of observation. These maps show the areas with significant transit ridership where transit trips originate or terminate, not the full geographic coverage of the three transit agencies. The unit of analysis is a census tract.

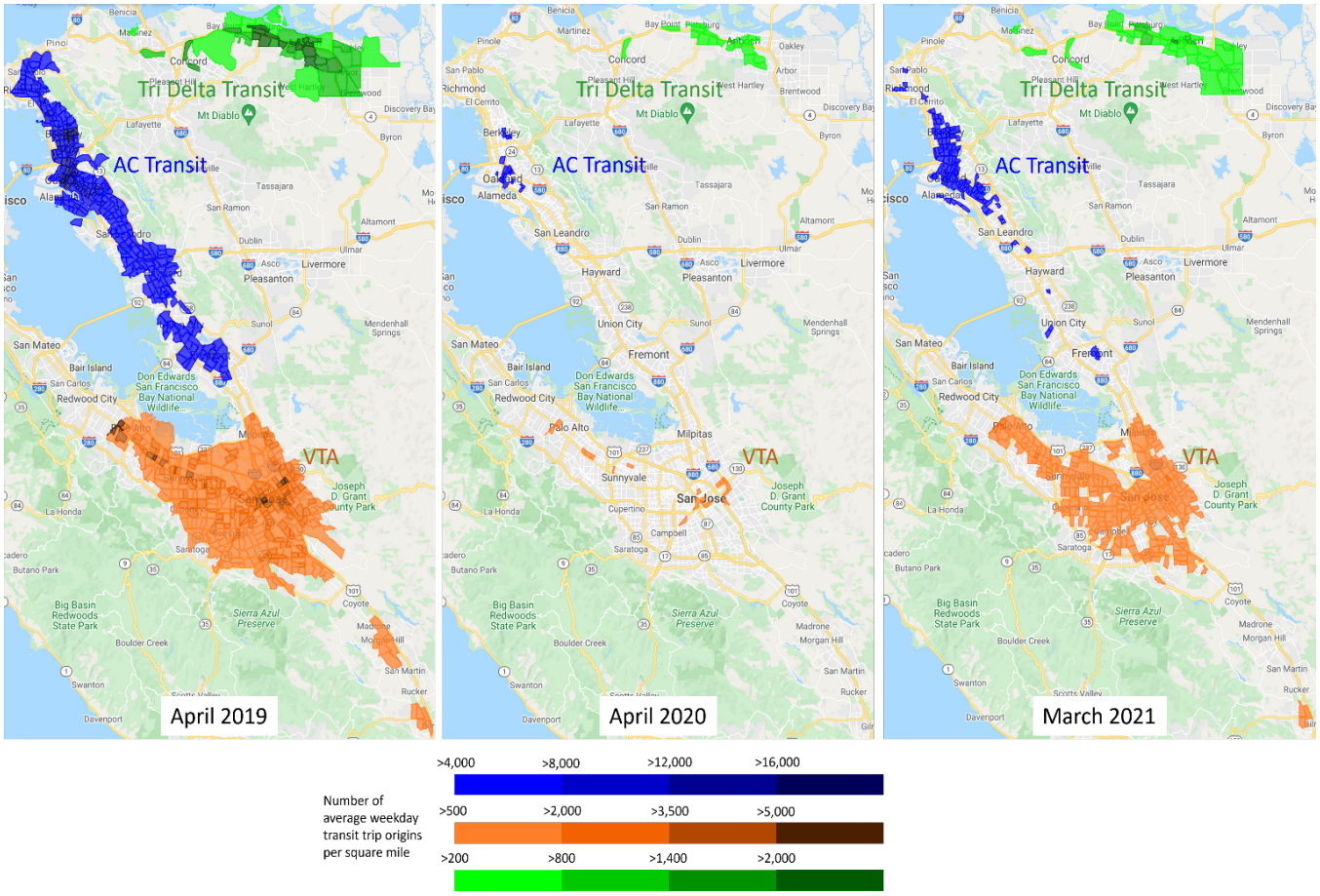

Figure 2. Areas with most active AC Transit, VTA and Tri Delta Transit ridership in April 2019, April 2020 and March 2021. Color intensity corresponds to the intensity of transit usage.

As the San Francisco Bay Area went into lockdown, transit activity ceased near university campuses (UC Berkeley, Stanford, San José State University, Santa Clara University, California State University East Bay, etc.), community colleges and high schools; and went down considerably near medical centers (Highland Hospital, Santa Clara Medical Center, Alta Bates and Kaiser Permanente campuses)

and shopping malls. Transit activity practically stopped in wealthy neighborhoods, such as Kensington. All this is evident from the two maps — for April 2020 and March 2021 — in Figure 2.

It is interesting to note that low-income areas of Oakland and Richmond with similar socioeconomic and demographic characteristics used to have high transit ridership in 2019, before the pandemic. During COVID, however, transit activity in Richmond dropped almost to zero, while it remained relatively high in Oakland. Our interpretation of this phenomenon is that Oakland, as opposed to Richmond, is a sanctuary city (Vaughan, J.M. and Griffith, 2021). As such, it hosts large number of undocumented immigrants who cannot not rely on unemployment benefits but need to work to make their living. Public transit is their means of getting to work.

In addition to basic changes in ridership, we looked at the following parameters for each of the three agencies' service areas: housing (ownership vs. renting); property value and the cost of rent; household income; unemployment and poverty rates; and race, to determine how these factors might be associated with those changes. We also looked at crime, but did not identify any particular relationship between various types of crimes and transit ridership during the observation period.

In the AC Transit and VTA regions, the areas with the most active transit usage are those where over 75 percent of the population rent their homes. In the suburban region of Tri Delta Transit, the ratio of renters to owners is roughly 50/50. This is explained by the fact that median house value where Tri Delta Transit operates is 50 percent less than in the AC Transit region and 65 percent less than in the VTA region. However, even Tri Delta areas with cheaper houses and larger renter populations have more transit users than those where homeowners dominate.

For all three agencies, ridership is in reverse proportion to household income. The lower the income, the higher the ridership, has been a ubiquitous rule during the pandemic. Indeed, during this time, transit has been mostly used by people who have to go to work, but have no other means to get there other than public transit. These are typically essential workers and/or undocumented immigrants who cannot not afford losing their jobs. In the AC Transit and Tri Delta regions, these were predominantly Latino and Black riders. In the VTA region they were mostly Latino and Asian riders. These same groups of people also rely on transit to go grocery shopping and to carry on other daily activities. To infer the dependency between the socioeconomic level of the population and its usage of public transit, we selected five variables:

1. Average number of transit trips per square mile per weekday initiated or ended in a given census tract during the monitoring period;
2. Median rent;
3. Median household income;
4. Poverty rate; and
5. Unemployment rate.

Values for variables 2-5 were obtained by census tract from the American Community Survey (ACS) for 2019. Table 2 provides information about the five variables for the three geographic areas served by AC Transit, VTA and Tri Delta Transit. The results are presented as averages over the census tracts

covered by each transit agency and weighted by the tract's population. Here, transit ridership numbers are obtained in March 2021, and all other variables come from ACS 2019.

Table 2. Sociodemographic and travel characteristics of areas served by the three agencies.

	AC Transit	VTA	Tri Delta
Average Number of Trips / Sq. Mile	646	159	135
Average Median Rent	$ 1,872	$ 2,343	$ 1,773
Average Median Household Income	$ 110,346	$ 143,386	$ 83,617
Average Poverty Rate	11.41%	7.61%	12.96%
Average Unemployment Rate	5.07%	4.23%	8.35%

Since each census tract within the area of operation of our three agencies was represented by the five variables (features) listed above, we performed a cluster analysis on the set of feature vectors. The optimal number of clusters for this dataset is 3. As shown in Figure 3, the resulting three clusters — specified by colors red, blue and green — have distinct characteristics (see the star plot): Census tracts with the highest unemployment and poverty rates and the lowest housing rent and household income have also the highest transit ridership and form the red cluster (24.5% of the population); tracts where the values of all parameters fall in the middle form the blue cluster (47.8% of the population); and tracts with the lowest transit ridership also have the lowest unemployment and poverty rates and the highest housing rent and household income and constitute the green cluster (27.7% of the population).

Before COVID, in 2019, this pattern was less pronounced. For example, many commuters were using transit for convenience, to avoid driving in heavy traffic and parking issues. This was especially true for those who worked in San Francisco, while living in the East Bay. Similarly, in Santa Clara County there were a large number of white-collar commuters, especially near light rail and regional train stations.

Other categories of transit users before COVID included elderly people, students, and university employees and visitors. Elderly people who no longer drive themselves, generally view public transit as means of independence. They use it to run errands , or to return home from appointments. Students generally do not own cars and rely on public transit. Some university employees, especially those commuting from afar, also use public transit. Hence, there is usually high transit ridership around university campuses. All these categories, commuters, elderly riders, students and university affiliates, stopped using public transit during COVID almost completely.

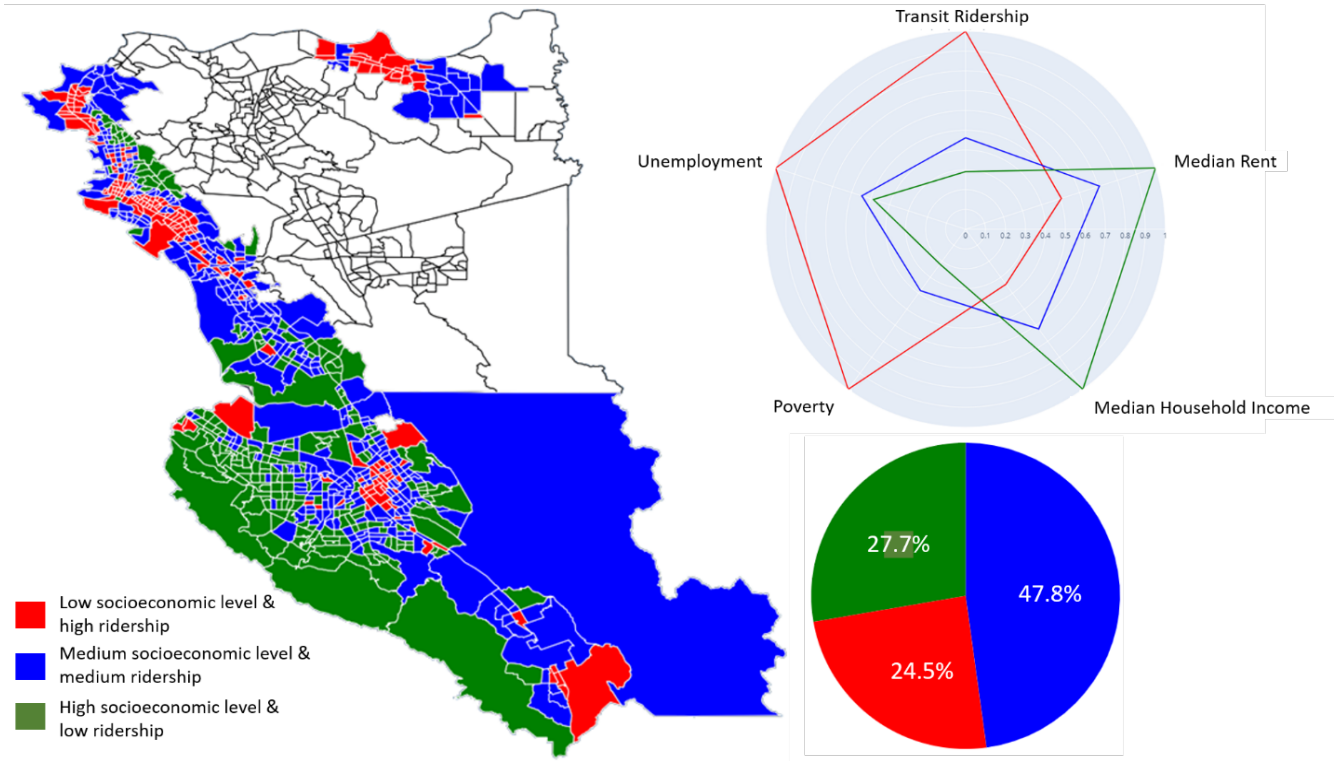

Figure 3. Cluster analysis of census tracts based on five parameters. (A) geographic coverage, (B) parameter characterization and (C) population breakdown. Here, Unemployment, Poverty, Income and Rent data are from 2019 ACS, and transit ridership comes from March 2021.

AC Transit and VTA reported that in the period of fare-free service (April-October for AC Transit, April-July for VTA) their buses were used by homeless people as temporary shelters. According to AC Transit, at that time homeless people constituted almost 15 percent of their ridership. This means that a notable portion of these agencies' ridership did not contribute to the state economic recovery during the fare-free periods. Even though Tri Delta Transit had the longest fare-free period (April-January) among the three agencies, it did not experience its buses being used as shelters for the homeless.

Our monitoring went through March 2021. Although some public transit recovery was evident, it was still very slow. AC Transit and VTA ridership was still below 50 percent and Tri-Delta Transit ridership was around 60 percent of their pre-COVID levels. Activity increased mostly around regional train stations, shopping malls and medical facilities. California lifted COVID restrictions in mid-June of 2021, and many universities and colleges opened their classrooms in the fall. In the fall of 2021, AC Transit ridership reached 64%, VTA – 52%, and Tri-Delta – 71% of their pre-pandemic levels.

Conclusion

During the year particularly hard hit by the COVID-19 pandemic, from March 2020 through March 2021, we monitored two large and one small transit agency in the Bay Area. As the lockdown was imposed, white-collar commuters, students and older adults stopped using public transit. Initially, ridership fell by 90 percent, and then for a year slowly climbed up to less than 50 percent for AC Transit and VTA, and up to around 60 percent for Tri Delta Transit. The pace of the recovery was not steady. Local ridership declines occurred during protests in June 2020, during fare reinstatements, and during the second COVID wave in winter 2020-21.

The findings can be summarized as follows:

- Public transit is an enabler of economic recovery. Even in the absence of revenue, when fare collection was suspended, it proved to be an indispensable means of transportation for categories of people that could not afford private alternatives and that had to get to work, providing essential services for the rest of us.
- In an urban area public transit is most effective on fixed routes where the service frequency that prevents overcrowding should be maintained.
- To facilitate the implementation of the previous two statements, transit agencies should receive sufficient public funding to avoid dependence on fare-related revenue.
- Transit ridership recovery could go faster than it did provided that the potential riders were convinced in its safety, and it could offer a competitive alternative to private cars in terms of travel time reliability. This could be partially achieved by increasing the frequency of service.
- Expanding on the previous statement, an important measure of a public transit system should be reachability – that is, the desired destination should be reachable within reasonable time from the moment one wants to start their journey. Transit agencies generally do not address this problem. Their main performance metric is ridership. Based on this metric, they optimize their routes and schedules. Many of them also consider accessibility an important factor. Reachability, however, cannot even be assessed by an individual agency. It requires an approach on the level of a regional transit system.
- A considerable ridership portion has not recovered by the fall of 2021, because people continue working remotely.
- Transit recovery is underway, but as of early 2022, it goes very slowly, and the impacts of the latest omicron variant are yet to be fully known.

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