Next Generation Customer Information System

Stakeholder Engagement Report

Originally released September 2018
Revised June 2020

CONTENTS

EXECUTIVE SUMMARY

In 2001, the San Francisco Municipal Transportation Agency (SFMTA) revolutionized the transit-riding experience by implementing NextMuni: the nation's first large-scale real-time transit information system designed to predict when transit vehicles would arrive. Provided by NextBus (now a subsidiary of Cubic), this information system fundamentally changed how people used Muni by delivering vehicle arrival predictions through signs at stops, mobile apps, and other means.

In the intervening years, however, San Franciscans have grown accustomed to a vastly different technological landscape that continues to redefine the transportation industry through on-demand service offerings and access to trip information via mobile devices throughout their travel. Seeking to stabilize and increase ridership, transit operators like the SFMTA are working to adapt and innovate in this rapidly-changing environment.

With the existing system nearing the end of its useful life, the SFMTA is investing in the **Next Generation Customer Information System** to empower Muni customers to confidently take mass transit to their destinations quickly and reliably.

In 2017, the SFMTA embarked on an extensive public outreach effort, including a comprehensive survey, concept testing and ride- along interviews, to shape the features and functionality of the new system. Major elements of the system include:

- Employing more sophisticated and accurate vehicle arrival predictions
- Implementing alternatively-powered signage at unpowered shelters and stops to expand customer access to information
- Reducing travel times by showing nearby alternative routes with shorter waits on digital signage at stops
- Balancing capacity by providing crowding alerts and suggesting parallel services with space available
- Strengthening network connectivity by showing transfer connection times on-board vehicles
- Communicating service delays and disruptions on-board vehicles
- Providing real-time stop and route accessibility information (e.g., elevator/escalator outage alerts) to facilitate travel for seniors and persons with disabilities
- Improving the rider experience via an enhanced mobile platform
- Using data to better understand customer preferences and improve service and operational planning

The Next Generation Customer Information System reflects an agency-wide effort to improve Muni service for everyone who lives in, works in, or visits San Francisco.

BACKGROUND

The SFMTA's Next Generation Customer Information System marks the latest step in the evolution of real-time transit information.

Two decades ago, transit systems relied solely on published timetables to communicate the arrival times for buses and trains. In San Francisco, a city with high levels of congestion which contributes to bus and rail delays, the Muni transit system used to publish only general schedule information to avoid disappointing customers if their vehicle did not arrive on time. Timetable booklets did not list specific times for most trips and instead provided scheduled service frequency. As a result, customers would venture out to their stop and hope that Muni would come shortly. In reality, customers could end up waiting a highly variable amount of time.

In 1999, NextBus conducted a pilot program of real-time information on the 22 Fillmore line. Digital displays at shelters on the route showed predicted vehicle arrival times, giving customers a much better expectation of how long they would have to wait for Muni. After this successful demonstration project, the SFMTA contracted with NextBus in 2001 to launch the nation's first large-scale real-time transit information system that became known as NextMuni.

NextMuni revolutionized public transportation in North America by making transit much easier to use. Later adopted by many other transit systems, this basic model continues to deliver vehicle arrival predictions through countdown signs located at waiting shelters and stations, and now through mobile apps and online.

NextMuni's design has not fundamentally changed since its inception. Meanwhile, technology has dramatically shaped the transportation landscape. People have grown accustomed to on-demand service offerings and access to trip information via mobile devices throughout their travel. These innovations have disrupted the transportation industry, providing people with more customized services but also causing widespread impacts from a systemwide perspective.

Once at the vanguard of American public transportation, the SFMTA's original real-time information system is nearing the end of its useful life. It is not feasible to maintain the core predictions platform of the current system procured in 2001 and simply make cosmetic changes to hardware and software systems. Consequently, the SFMTA is eager to leverage the many innovations in technology and transportation that have occurred in the nearly two decades since the original system was installed. In doing so, the SFMTA seeks to upgrade to a revolutionary Customer Information System that exceeds customer expectations.

CONTEXT

After increasing 36 percent between 1995 and 2014, U.S. transit ridership has begun to fall, even as the economy and demand for transportation services have grown — with buses nationally plunging a particularly steep 9 percent since 2014. Some speculate that low gas prices, gentrification, Transportation Network Company (TNC) services such as Uber and Lyft, and rising car ownership are driving this decline. In this environment, annual Muni ridership

declined by approximately 6 million between 2014 and 2019, or 2.6%, despite San Francisco's 4.5% population growth.

Left unaddressed, these ridership losses could fuel a cyclical downward spiral of heavier congestion, slower service, fare increases and service reductions leading to further ridership losses. While ridership has increased In San Francisco recently, the threat of the nationwide trend away from transit is especially alarming. A 47-square mile city surrounded by water on three sides, San Francisco is projected to face a 26-percent population increase from 870,000 to 1.1 million residents. There is simply no room to accommodate more cars.

As this trend continues and customer behavior adapts to new transportation options, it is imperative that the SFMTA pursue ridership-growing initiatives and that the transit industry evolve its current models and understanding of mode choice to remain competitive.

In recent years, San Francisco's transportation environment has been radically upended by an explosion of app-based carsharing, bikesharing, private commuter vans, scooters, and Transportation Network Company (TNC) ride-hailing services. While many of these services deliver personalized mobility by facilitating end-to-end travel with minimal trip-planning involved, they come at the expense of the greater public's transportation needs. According to *TNCs Today: A Profile of San Francisco Transportation Network Company Activity*, a study developed by the San Francisco County Transportation Authority (SFCTA) in partnership with researchers from Northeastern University, TNCs comprise 20 to 26 percent of vehicle trips in Downtown and South of Market: areas where Muni service is the most robust, but also most vulnerable to congestion (see Figure 1).

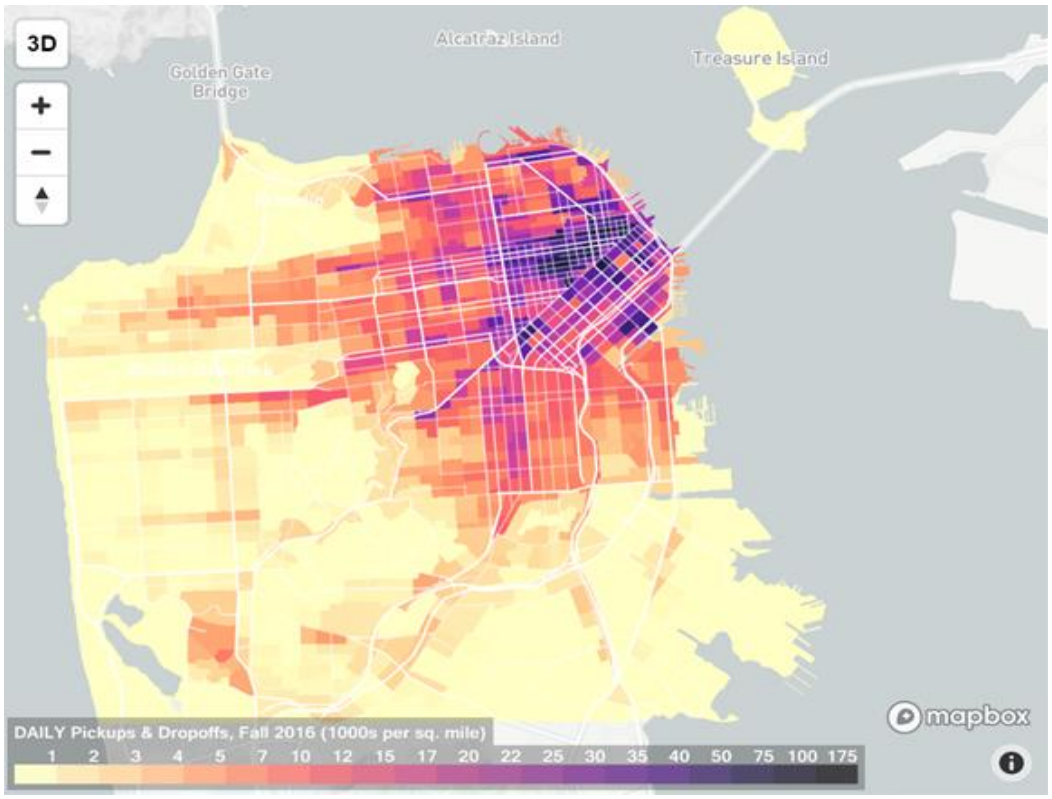


Figure 1: TNC Pickups & Dropoffs, Fall 2016

Moreover, the SFMTA has observed that the arrival of TNCs may have negatively affected ridership in part due to the prevalence of associated advertising on third-party public transportation mobile applications (see Figure 2). The outreach and research outlined in this report support the conclusion that TNC services may siphon ridership away from transit. This shift is alarming as it could impact the livability and sustainability of heavily-congested, dense cities like San Francisco.

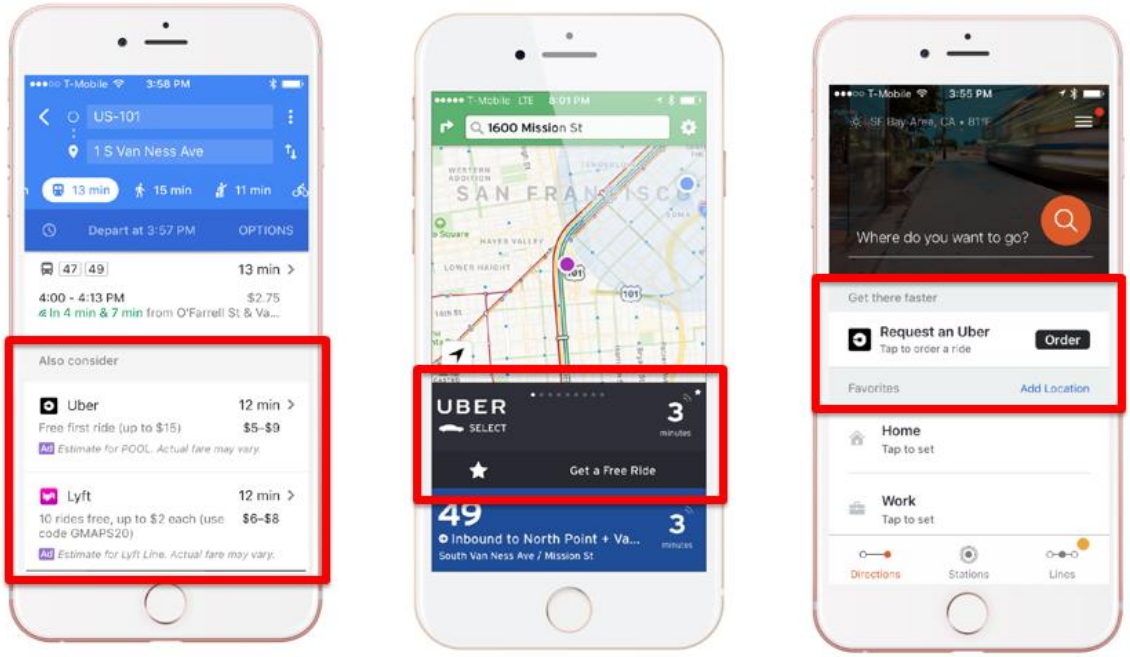


Figure 2: Popular Transit Apps Prominently Advertise TNCs

The SFMTA is thus investing in the next generation of real-time customer information to make Muni the preferred travel choice of San Francisco. By adopting technological advancements designed to align with the transportation landscape of the future, the Next Generation Customer Information System can potentially recapture, retain, and grow transit ridership. Critically, much like the first-generation system, the SFMTA can help establish best practices for real-time information, paving the way for industry-wide adoption and transit revitalization across the country.

OUTREACH METHODOLOGY

Reflecting a customer-centric approach, the SFMTA conducted extensive public outreach to assess the potential for the Next Generation Customer Information System to build transit ridership, identify how customers would react to contemplated new features, and inform the next generation system's design.

This process included a comprehensive online survey and in-person qualitative research. The SFMTA sought to understand how different customers characterize, locate, and use valuable information and the specific contextual factors, reasoning, and motivations behind mode choice and information needs. Within this research, the SFMTA also created space for customers to express any other features they would like to see. This outreach has allowed the agency to validate the new system's potential to increase mode share and to uncover and incorporate customer information needs into system requirements.

This effort included focus groups involving participants with and without disabilities from diverse sociodemographic backgrounds, as well as a comprehensive multi-lingual survey of over 30 questions in both online and paper formats.

Survey

The comprehensive online survey, distributed from May to October 2017, sought to capture customer travel patterns, inner reasoning, reactions, and preferences pertaining to transit (the themes and types of questions asked are captured in Table 1). This information helped the SFMTA address its key objective: assessing how customer information could influence travel behavior towards transit.

Some key questions this research helps answer include:

- How long are customers willing to wait for transit?
- How do customers perceive that transit is "on-time" versus "late"?
- What are the salient factors influencing travel choice?
- Can providing real-time information help retain transit customers who might otherwise use another mode?
- How might third-party apps influence travel choice?
- How can real-time information improve willingness to transfer between routes?
- How can real-time information reduce behavioral differences across demographic groups?

Table 1: Survey Topics

Survey Topic	Description
Transportation System Usage	
Transportation Mode Usage	Frequency of use of Muni, other transit systems, walking, bicycling, Transportation Network Companies, taxis, employer shuttles, driving alone and carpooling
Willingness to Wait	Maximum desired wait time without any real-time information during the day, during the evening and when transferring
Direct vs. Transfer Trips	Frequency of riding a direct route vs. transfers
Fare Payment	Fare Media Usage (for example, unlimited-ride passes vs. pay-as-you-go)
Muni Route(s)	Regularly-ridden Muni routes
Customer Information	
Information Tools Usage	Usage of different information tools (for example, shelter signs, mobile apps, website trip planners, information hotline)
Mobile Apps	Usage of different mobile apps
Opinions of Existing System	Five-point scale rating of different elements of the existing system
Desired Features	Free-form response
Situational Questions (Stated Preference)	
Mode Share-Direct Trip	Mode preference in four scenarios when going from work or school: • Customer arrives at stop. Countdown sign predicts a 20-minute wait • Countdown sign displays an earlier-arriving alternative route 3 blocks away • Customer checks smartphone before walking to stop, which predicts a 20-minute wait • Customer's smartphone app also advertises TNC services
Mode Share-Transfers	Mode preference in two scenarios when going from work or school: • Smartphone app shows two routes to reach the destination but not the connection time • Smartphone app also shows estimated connection time
Crowding	Mode preference when countdown sign shows a currently full vehicle followed by a vehicle currently with space available
Demographic Questions	
Demographics	Residential ZIP code, age, ethnic background, gender identity, annual household income and disability
Motor Vehicles	Number of motor vehicles in household

Table 2: Survey Demographics

Category	Percentage
Age (n=5,789)	
Under 18	2.7%
18 to 24	8.1%
25 to 34	25.8%
35 to 44	20.1%
45 to 54	18.2%
55 to 64	12.2%
65 and above	12.9%
Gender Identity (n=5,628)	
Female	47.3%
Male	51.7%
Another Gender Identity	1.1%
Household Income (n=5,262)	
Less than $25,000	12.7%
$25,000 to $49,999	13.4%
$50,000 to $74,999	15.1%
$75,000 to $99,999	12.2%
$100,000 to $124,999	12.3%
$125,000 to $149,999	8.1%
$150,000 to $199,999	10.3%
$200,000 or more	16.1%
Race/Ethnicity (n=5,494)	
Asian/Pacific Islander	22.8%
Black/African American	3.2%
Latino/Hispanic	7.3%
Native American	0.3%
White/Caucasian	57.5%
Another Race/Ethnicity	2.9%
Multiracial	6.0%
Disability (n=5,824)	
Yes	8.6%
No	91.4%
Motor Vehicles in Household (n=5,850)	
0	30.6%
1	42.0%
2	19.7%
3 or more	7.7%

To publicize the survey, the SFMTA leveraged press releases, social media, agency listservs and notices on digital signs at shelters and on buses. To increase participation among underrepresented populations, the SFMTA also provided Chinese and Spanish translations, and distributed paper versions to various stakeholder groups and community organizations. With 5,856 people completing the 10-to-15-minute survey, this sample size reflects a margin of error of ±1.5% at a 95 percent confidence level.

In order to capture diverse feedback and to isolate key demographic factors influencing mode choice, the survey asked voluntary questions on age, residential ZIP code, ethnic background, gender identity, household income, disability status and vehicle ownership. These demographic questions came at the end of the survey to avoid response bias. Each demographic question had at least a 90 percent completion rate.

Based on these responses as shown in Table 2, the SFMTA concludes that the survey has a geographically-representative sample from San Francisco and nearby counties fairly reflective of Muni ridership. Applying these results, the SFMTA conducted a series of binary logistic regressions to the data to determine which demographic factors most impacted transit mode choice with respect to real-time information. The results of these analyses are discussed in the following section.

Qualitative Research

To supplement the survey, the project team conducted focus groups with various stakeholders, including demographic groups that might potentially be underrepresented in the survey. This included Senior and Disability Action, Independent Living Resource Center, LightHouse for the Blind and Visually Impaired, and the Youth Commission. As well, the project team met with community stakeholders in the Bayview, Chinatown, the Mission, Potrero Hill, and Visitacion Valley.

In addition, the project team held "ride-along" immersive field research sessions with customers to observe and better understand their travel behavior. Research was conducted in diverse neighborhoods throughout San Francisco. Focus groups and 1:1 interviews lasted 90 minutes. Discussions focused on how different customers characterize, locate, and use information.

Summary

With its mixed quantitative and qualitative methodology, large sample size, and focus on underrepresented populations, the outreach conducted by the SFMTA provides a rich data set to analyze how the next generation of real-time information could influence customer perceptions and their resultant mode choices. Moreover, with results representing a diverse ridership base, the collected data also provides empirical evidence into how demographic variables can shape travel decisions among disaggregated subpopulations.

Most importantly, research results (described in the following section) demonstrate how new types of real-time information – such as alternative routes and transfer connections – could help

transit providers retain and increase ridership, and present an opportunity for the SFMTA to assist transit professionals and researchers elsewhere facing similar issues.

FINDINGS

Through its extensive mixed-method research, the project team made the following findings about how customers interpret and utilize real-time information, as well as how customers perceive the utility of the existing system:

Importance of Predictions

Key Findings	Implication
The vast majority of Muni customers rely on real-time arrival predictions.	The existing system remains a critical investment the SFMTA has made in improving the transit customer experience. It is therefore imperative that predictions and real-time information are accurate and meet the needs of customers.

When asked when they check for their vehicle arrival when riding Muni, a near-unanimous 94 percent of customers said they check while waiting at their stop at least "Sometimes," "Often," or "Always" (see Figure 3). This could be via the availability of signage or from a mobile app. A significant 79 percent of customers said they check while walking to their stop and 87 percent indicated they check before walking to their stop.

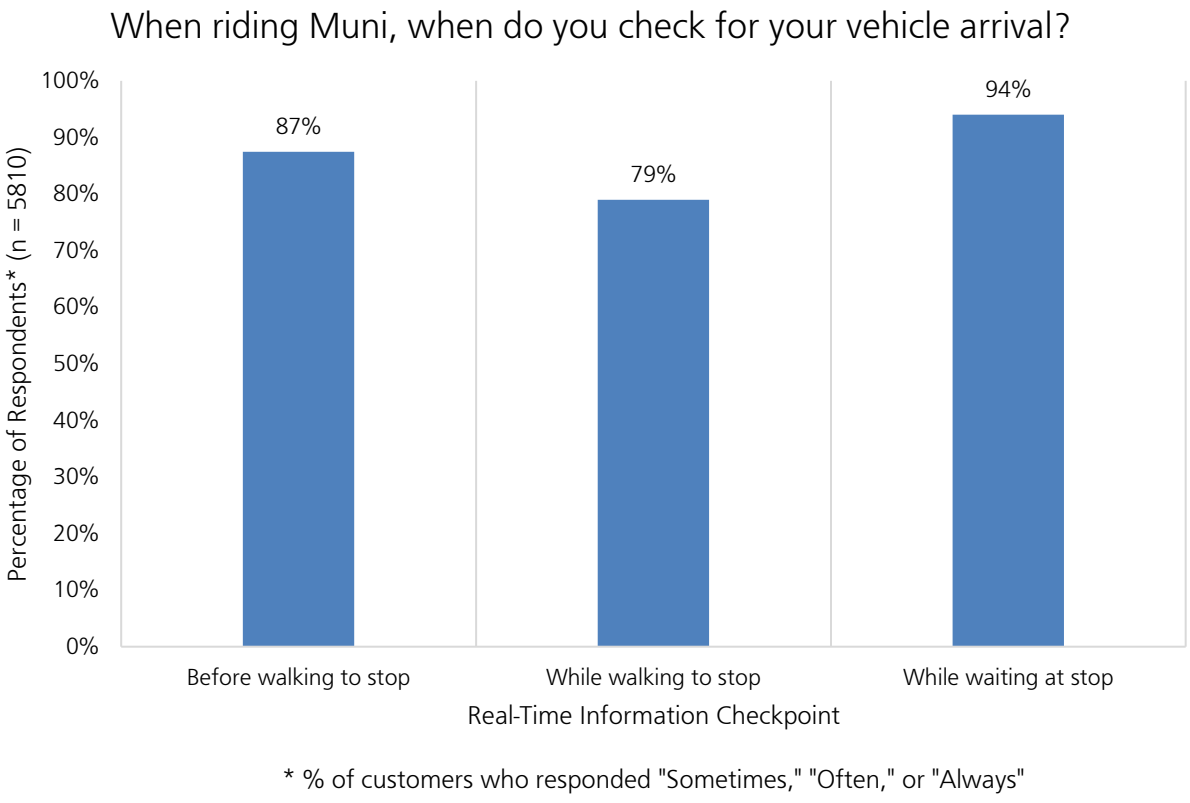


Figure 3: Customer Utilization of Real-Time Vehicle Arrival Predictions

Service Reliability

Key Findings	Implication
In lieu of on-time performance, customers use real-time information to assess whether their bus was late or on-time. While important, survey respondents reported not believing the SFMTA's predictions to be accurate, rating predictions a 2.5/5 on the online survey.	Improving prediction accuracy of real-time information can enhance customer perceptions that Muni is "reliable" and "on-time," thus increasing satisfaction and possibly one's willingness to ride transit.

Continuous, accurate real-time information is paramount to meeting customer expectations for service reliability. Transit systems that operate in mixed traffic – the vast majority of service in the United States – have challenges maintaining scheduled service frequency and consistent headways. This difference between actual and scheduled service is due to traffic congestion, variable passenger loads, the deployment of wheelchair ramps, and other factors. All Muni routes, including the Muni Metro light rail system, operate all or portions of their services on surface streets, making them likely to encounter headway variability.

Per City Charter Section 8A.103, "a (Muni) vehicle is considered on-time if it is no more than one minute early or four minutes late as measured against a published schedule that includes time points." Focus groups revealed that SFMTA customers rarely consult the official schedule because service is generally frequent, and timetables are only available online. When asked about vehicle "lateness," focus groups reported that they define a late vehicle as one that does not arrive according to real-time predictions.

This suggests that improving prediction accuracy can enhance perceptions that Muni is "reliable" and "on-time," thus increasing satisfaction and possibly one's willingness to ride transit.

Existing Trip-Planning Information Quality

Key Findings	Implication
When asked to rate the quality of existing trip-planning information, customer responses were mixed. Aggregating the responses of customers who rated the quality of such information as "Excellent," "Very Good," or "Good" showed that only a few elements of key trip-planning information provided by the SFMTA are considered good by a slim majority of customers.	With inadequate trip-planning information, customers may be tempted to utilize other sources of information to plan their trips or to not ride Muni at all. Many third-party providers that these customers may turn to also advertise transportation services incompatible with the SFMTA's sustainable transportation goals.

As seen in Figure 4, on a scale of 1 to 5 (1 = "Poor," 3 = "Good," 5 = "Excellent"), only 49 percent of survey respondents rated current prediction accuracy as either "Excellent," "Very Good," or "Good." (The average response was a 2.5.) This likely contributes to the widespread perception of Muni as late or delayed.

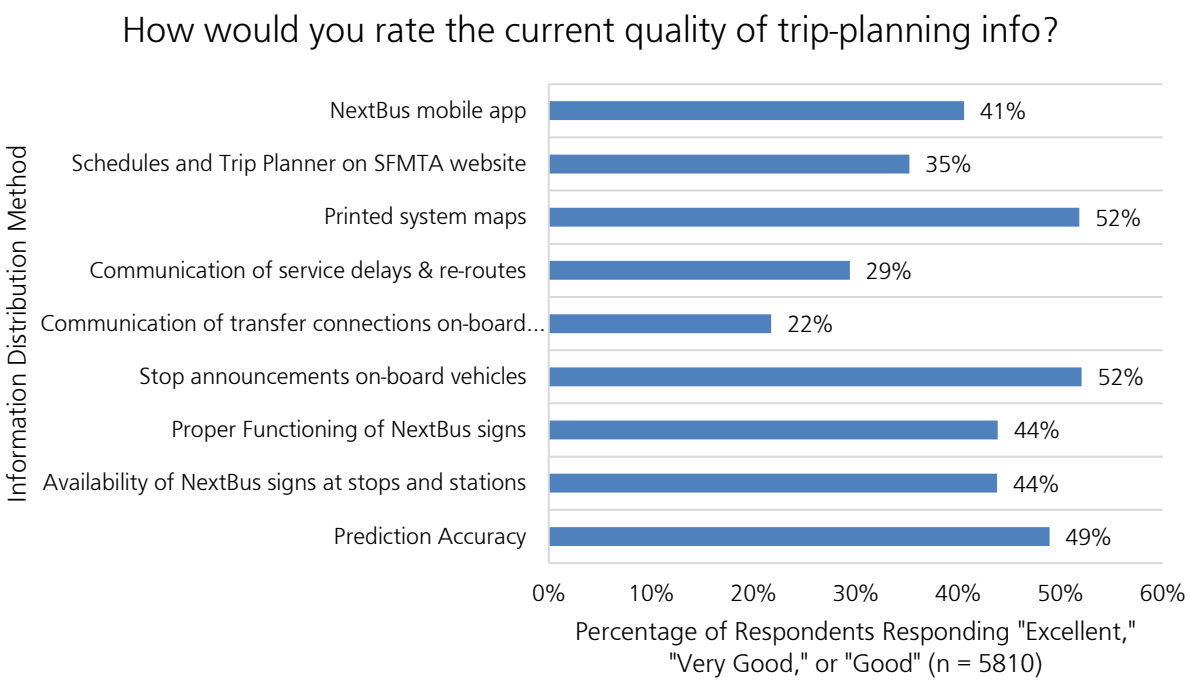


Figure 4: Customer Perceptions of Existing Trip-Planning Information Provided by the SFMTA

When service disruptions occur, the existing customer information system is unable to generate real-time information about the incident other than text alerts manually entered by Transportation Management Center staff. Unsurprisingly, only 29 percent of respondents ranked the current communication of service delays and reroutes as either "Excellent," "Very Good," or "Good." (The average response was a 2.0.) By providing real-time updates on unplanned service changes and offering alternatives, the SFMTA anticipates that the Next Generation Customer Information System will reduce the impacts of delays and disruptions for customers, which in turn will improve perceptions of system reliability.

Service Frequency

Key Finding	Implication
On average, most survey respondents were willing to wait only 10-15 minutes for their next Muni vehicle, and even less if a transfer is required. While the current average willingness to wait uncovered through the survey (10-15 minutes) aligns well with scheduled SFMTA daytime route frequencies, it does not align well with scheduled frequencies during the night and off-peak periods (20-30 minutes).	Real-time information is particularly important to customers riding at night, during off-peak periods, and for transfers because service is often less frequent and missing a bus has a more adverse impact in terms of time lost.

While Muni offers some of the highest levels of transit service in the country, there are also weaker parts of the network (see Figure 5). In some outer neighborhoods, or in general during evenings and weekends, many routes operate every 20 to 30 minutes.

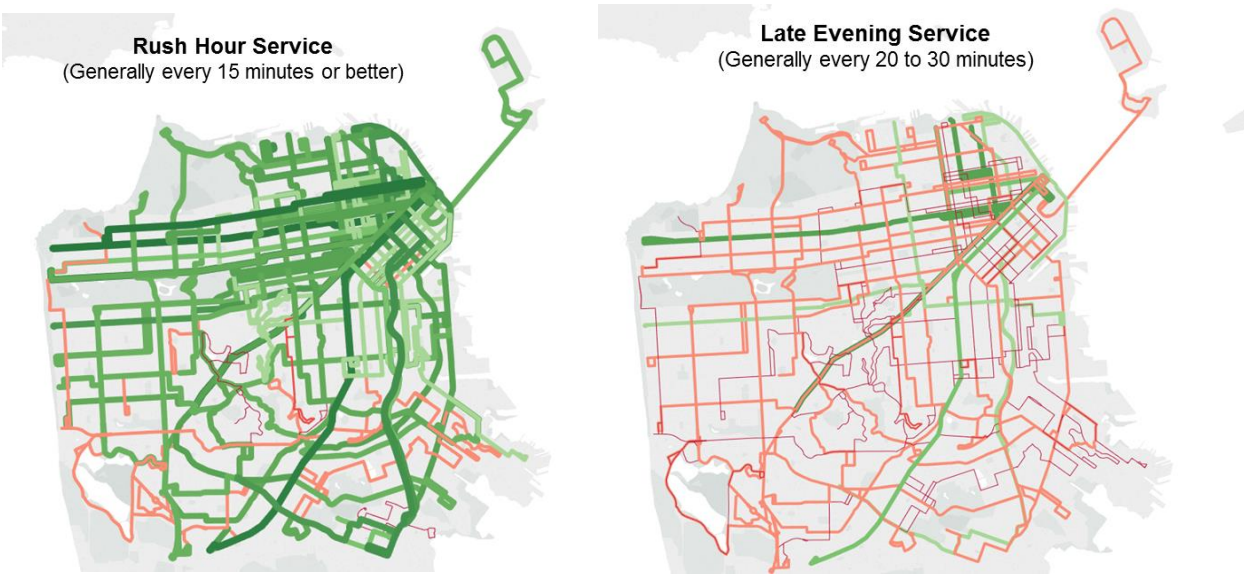


Figure 5: Muni Service Frequency (Green indicates service 15 minutes or better)

Even with this high level of service, customer expectations of maximum waiting times are also high. The survey asked respondents to indicate how long they would be willing to wait if they had just arrived at a stop without real-time information. The median respondent reported a willingness to wait between 10 to 15 minutes (see Table 3). Few people are willing to wait 20 minutes or more, which is how often many routes are scheduled to operate at night or other off-peak periods, or when there are service gaps. The willingness to wait also declines noticeably for transfers.

Table 3: Percentage of Customers Willing to Wait for Transit without Real-Time Arrival Information

Waiting Time Until Next Muni Vehicle	During the Day (n=5,856)	During the Evening or Night (n=5,856)	When Transferring (n=5,856)
5 min	97%	94%	93%
10 min	73%	67%	59%
15 min	35%	34%	22%
20 min	14%	15%	8%
30 min	5%	5%	3%

While Muni's frequent service during the daytime aligns well with customer expectations, the discrepancy between willingness-to-wait and service frequency suggests the importance of having real-time information, particularly during off-peak periods and for transfers. Accurate real-time information allows customers to better manage their time and potentially alters the way they perceive waiting times.

OPPORTUNITIES

The SFMTA project team also uncovered ways in which the Next Generation Customer Information System could positively influence ridership.

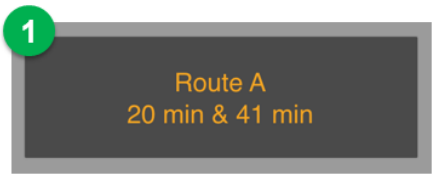
Transit Customer Information and Mode Choice

To measure how real-time information delivered at different times and places could impact mode choice, the SFMTA designed situational questions to test the following questions:

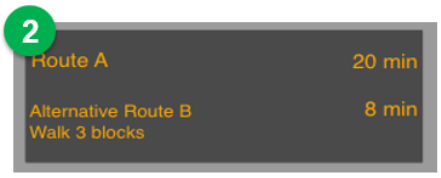
- Can providing nearby alternative routes with shorter waits help retain transit customers who might otherwise use another transportation mode?
- How do customers respond to transit information presented in SFMTA-managed apps vs. third-party apps that often advertise private ride-hailing services?
- Does real-time transfer information increase the willingness to transfer between routes?

The survey asked respondents to imagine scenarios where they were going home from work or school and had to wait 20 minutes, which is not uncommon if there is a service gap or during evenings and weekends. Suspecting that few respondents would be willing to wait that long, the project team designed questions to determine whether different types of real-time information could effectively extend one's willingness to wait. Without access to *any* real-time information, only 14 percent of respondents indicated they would wait all 20 minutes before abandoning transit and seeking other transportation.

Figure 6 illustrates tested scenarios. In Scenario 1, respondents arrive at their stop and see a digital sign predicting a 20-minute wait. The survey asked customers what they did the last time they encountered a similar situation. In Scenario 2, the sign suggested an alternate route three blocks away arriving sooner. In Scenario 3, before walking to their stop, customers consulted their smartphone and saw their wait on SFMTA/NextBus mobile app would be 20 minutes. Finally, Scenario 4 was identical to Scenario 3 except that the user saw the wait prediction on a third-party app along with a TNC advertisement.

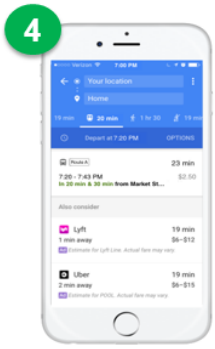


Shelter sign predicts a 20-minute wait



Shelter sign displays an earlier-arriving alternative a few blocks away

SFMTA/NextBus app predicts a 20-minute wait



Third-party app predicts a 20-minute wait

Figure 6: Tested Scenarios - Different Presentations of Real-Time Information

As shown in Figure 7, the presentation and content of real-time information influenced mode choice significantly, *even when Muni service itself did not change*.

In Scenario 1, only 45 percent of respondents took Muni, either waiting the entire 20 minutes or finding an alternative transit route on their own. Proactively suggesting an alternative route (Scenario 2) boosted Muni's mode share to 82 percent. When respondents checked the NextBus mobile app before walking to their stop (Scenario 3), 72 percent chose Muni. Finally, for the third-party app (Scenario 4), Muni's mode share fell by 7 percentage points.

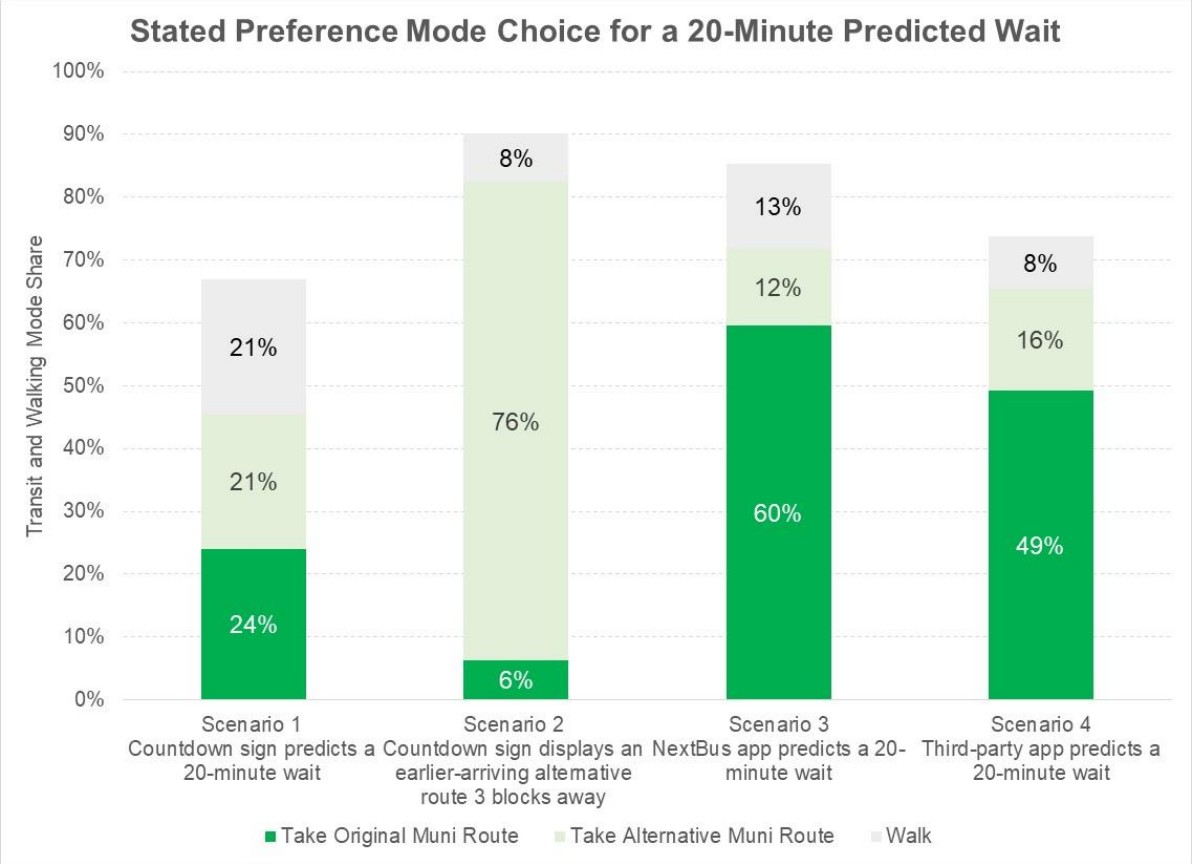


Figure 7: Stated Preference Mode Choice for Scenarios Involving a 20-Minute Wait

Demographic Variables Influencing Mode Choice

Key Finding	Implication
The more income a customer has, the more likely they are to abandon Muni service during a service delay.	Real-time information has the potential to increase customers' perceptions of reliability and in turn increase and retain ridership.
Customers living in TNC-dense ZIP codes (Marina, Hayes Valley, etc.) are less likely to ride Muni during a delay.	In TNC-dense areas, which often overlap with the densest and most frequent parts of Muni's network, and where there are generally many transportation options competing for customers, real-time information such as nearby alternative routes has the potential to steer customers toward public transit.

Because high-density TNC areas also overlap with the densest and most frequent parts of Muni's network (see Figure 1), there could easily be occasions where someone could take a nearby alternative Muni route rather than a TNC if the Next Generation Customer Information System informed them of that option.

To investigate the viability of this, the SFMTA conducted binary logistic regressions on customer demographics for each scenario to determine their potential influence mode share. Model results are described below (p-values were statistically significant at or below the 0.05 level).

Income

In recent years, rapid employment and population growth have contributed to widening income inequality, racial disparities, and gentrification in the San Francisco Bay Area. Coinciding with these broader economic and social trends, the proliferation of private transportation has also raised the prospect of a two-tiered, income-based transportation system. The analysis confirms that income strongly influences transportation choices.

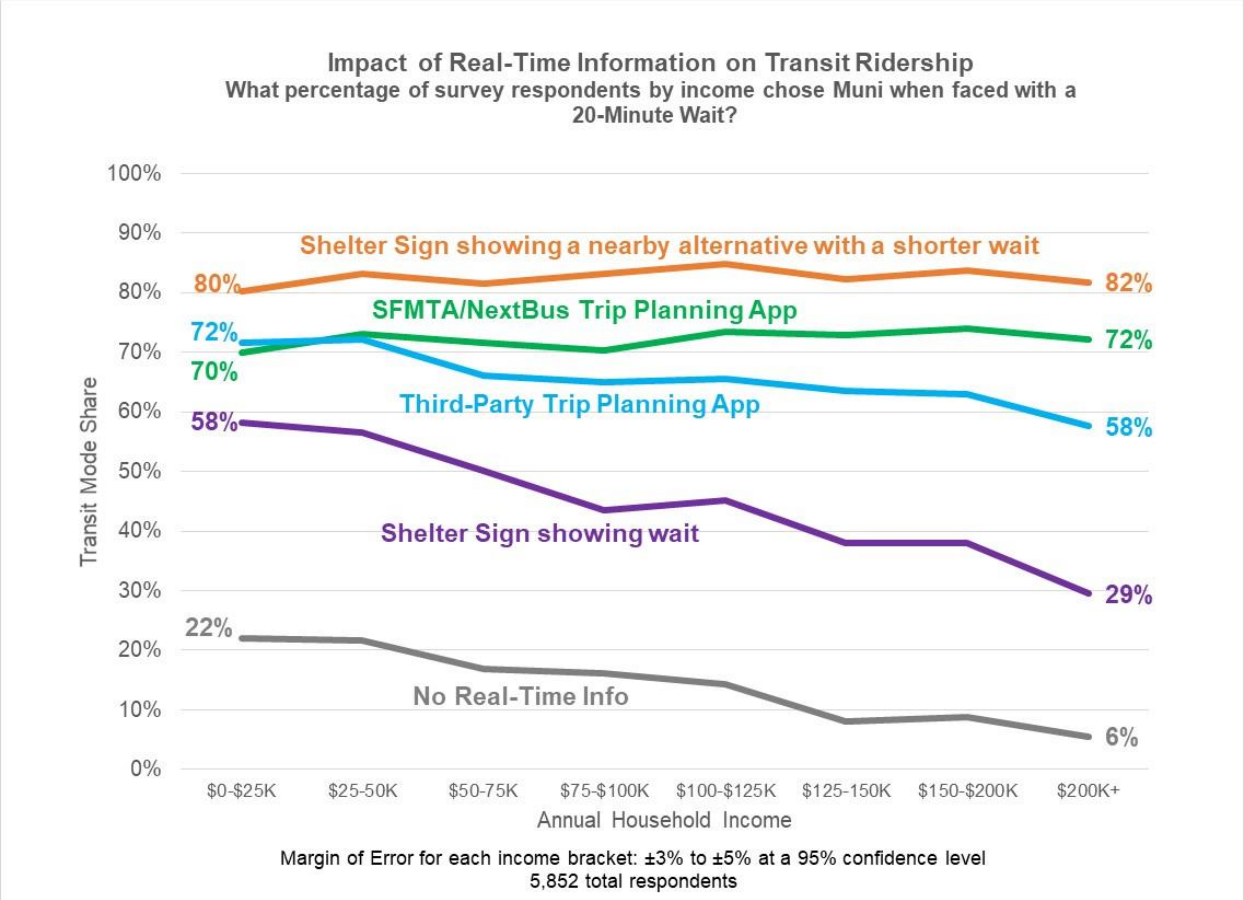


Figure 8: Stated Preference Transit Mode Share for Scenarios Involving a 20-Minute Wait, by Income

As shown in Figure 8, income had the strongest demographic influence on transportation choice, with Muni mode share declining as income levels increased. However, targeted and contextual information could mitigate its effect – in some cases, dramatically increasing ridership while virtually eliminating the influence of income altogether on mode choice. Simply providing a sign with the estimated 20-minute wait time boosted transit's mode share anywhere from 21 to 36 percentage points, depending on income. Showing an earlier-arriving alternative route within walking distance on the sign further increased the transit mode share an additional 22 to 53 percentage points, such that over 80 percent chose Muni across all income levels. Apps with real-time info also increased transit mode share, with a Muni app performing better than a third-party app with TNC ads as income increased.

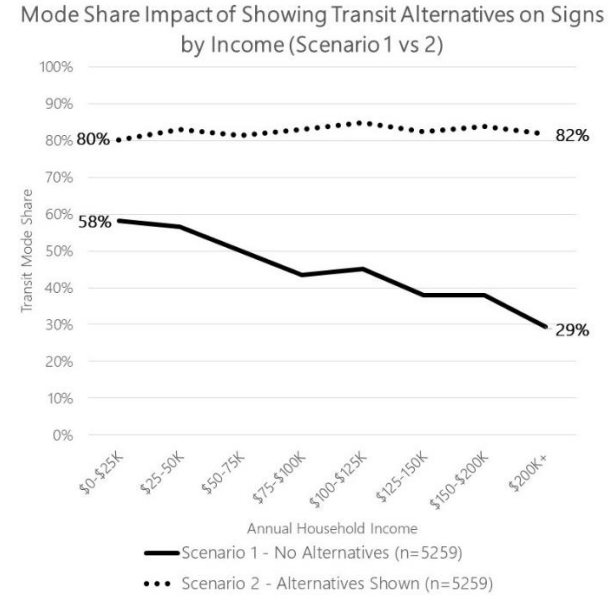
In the base case (Scenario 1), income accounted for up to a 29-percentage-point mode share difference between the lowest and highest income brackets (29 vs. 58 percent, Figure 9(a)). Figures 9(a) and (b) show how the Next Generation Customer Information System might alter customer behavior to sharply reduce or even virtually eliminate the influence of income disparities on transit mode share. Faced with waiting 20 minutes at a stop (Scenario 1), people are far more likely to shift away from Muni as their income increases. In contrast, when the stop's countdown sign offers a nearby alternative (Scenario 2) or customers can consult the SFMTA/NextBus app before walking to their stop (Scenario 3), income disappears as a statistically-significant variable. The income gap, however, reappears when customers see prediction information on a third-party app with a TNC advertisement (Scenario 4).

TNC Vehicle Density

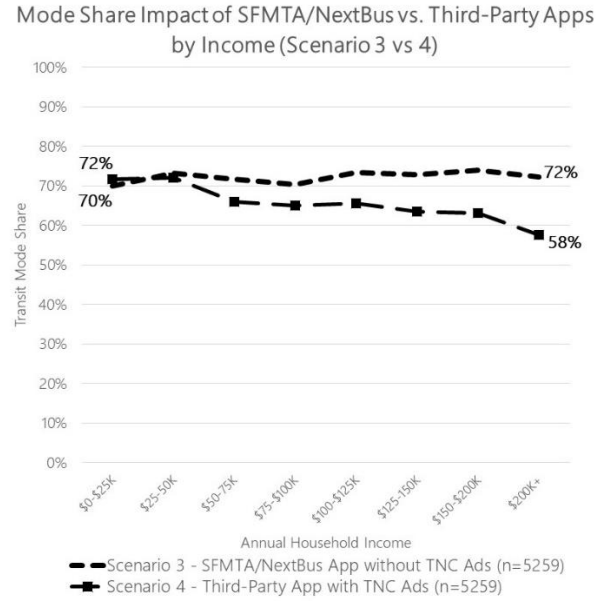
As shown in Figure 1, TNC vehicle trips are most highly concentrated in San Francisco's northeastern quadrant, followed by outlying commercial districts. To gauge whether TNC availability influences transit ridership, the analysis assigned San Francisco ZIP codes into two categories based on TNC density.

Combining both income and TNC density, Figures 9(c) and (d) show that people living in TNC-dense neighborhoods are statistically less likely to ride Muni in all scenarios, and that this gap generally holds across all income brackets. Most significantly, when faced with a 20-minute wait (Scenario 1), highest-income earners living in high-density TNC ZIP codes are 16 percentage points less likely to take Muni than highest-income earners living in low-density TNC ZIP codes (22 vs. 38 percent, Figure 9(c)).

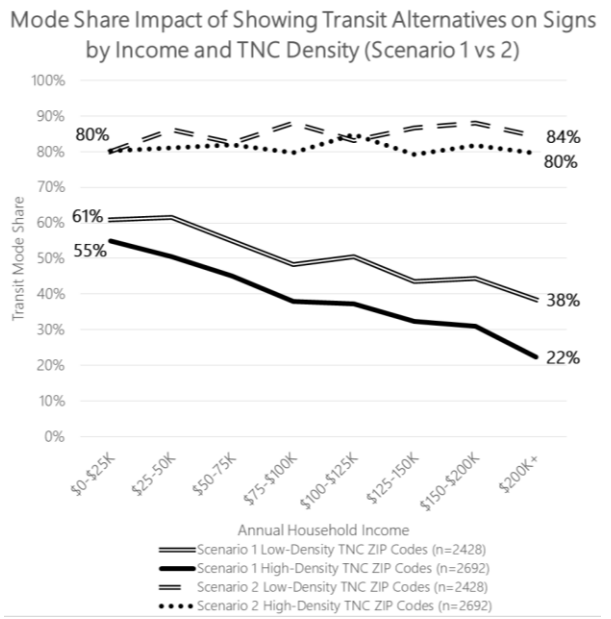
While these results suggest that the SFMTA currently might be losing significant ridership in high-density TNC areas, the Next Generation Customer Information System could alter this dynamic. Most strikingly, suggesting transit alternatives to avoid a 20-minute wait (Scenario 2) lifted transit mode share by 25 to 58 percentage points (55 vs. 80 percent at the lowest-income level and 22 vs. 80 percent at the highest-income level, Figure 9(c)). Because high-density TNC areas also overlap with the densest and most frequent parts of Muni's network (Figure 10), there could easily be occasions where someone could take a nearby alternative Muni route if the Next Generation Customer Information System informed them of that option, rather than giving up on transit.



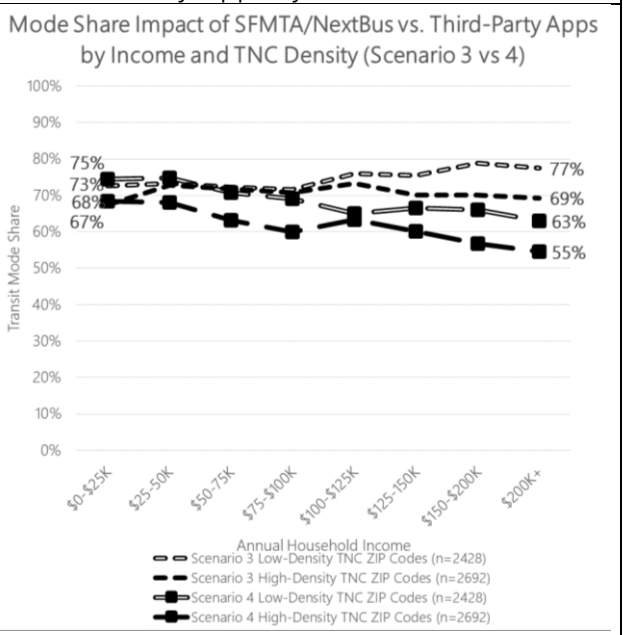
(a) Mode Share Impact of Showing Transit Alternatives by Income



(b) Mode Share Impact of SFMTA/NextBus vs. Third-Party Apps by Income



(c) Mode Share Impact of Showing Transit Alternatives by Income Bracket and ZIP Code-Based TNC Vehicle Density



(d) Mode Share Impact of SFMTA/NextBus vs. Third-Party Apps by Income Bracket and ZIP Code-Based TNC Vehicle Density

Figure 9: Stated Preference Transit Mode Share by Income and ZIP Code-Based TNC Vehicle Density

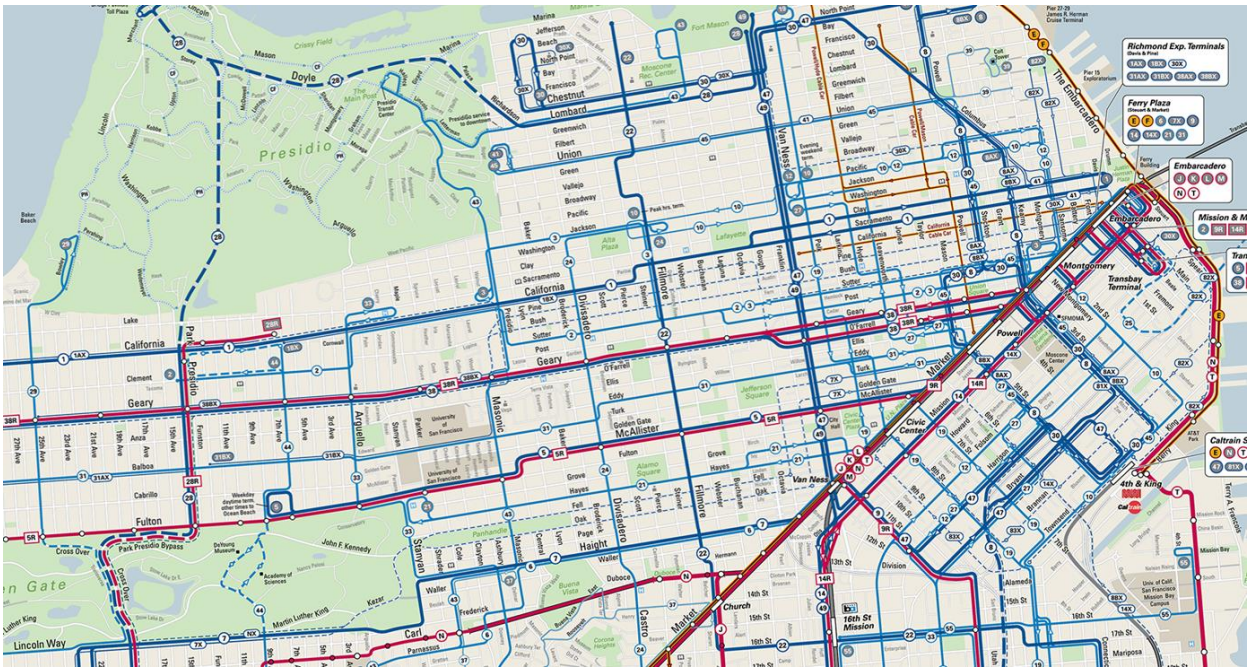


Figure 10: Muni Network Density and Alternatives

Other Notable Findings

Key Finding	Implication
Customers with prepaid passes are more likely to ride Muni than those who pay per ride. Pay-as-you-go customers might be more likely than pass holders to consider and choose other transportation modes for each trip.	In addition to increasing monthly pass usage, the agency may wish to design and promote other fare products that not only accommodate flexibility but also encourage more frequent transit use.
Providing transfer time predictions increased respondents' willingness to transfer between routes.	Real-time transfer information has the potential to keep customers in the Muni ecosystem.
When providing crowding estimate information, a significant percentage of customers stated that they lacked confidence in accuracy of such a prediction.	When designing how customers will experience real-time crowding and nearby alternative route information, accuracy is paramount.

Fare Payment Method

The analysis uncovered a correlation between fare payment method and mode choice. Of respondents stating they rode Muni at least four days per week, 34 percent reported paying per ride, despite likely riding enough to make purchasing an unlimited-ride pass financially worthwhile. While the causality is uncertain, the SFMTA hypothesizes that by not making an upfront financial commitment to transit, pay-as-you-go customers may be deliberating more about their options for each trip and choosing other transportation modes. Consequently, the number of pay-as-you-go respondents choosing transit is a statistically-significant 5 to 14 percentage points lower than the number of pass-holders depending on the scenario (see Figure 11).

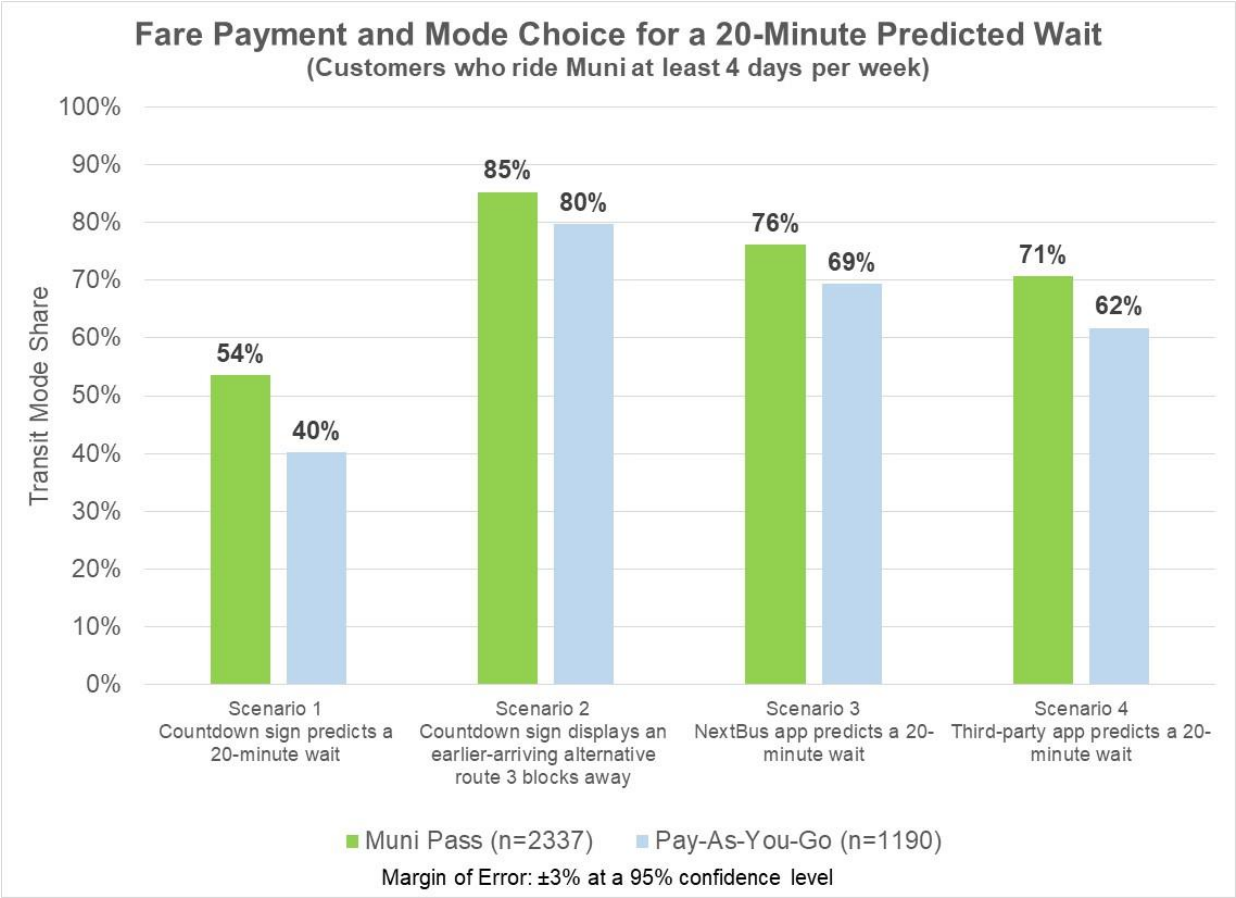


Figure 11: Fare Payment, Customer Information and Mode Choice

Transfers

Two questions asked customers how they would return home from work or school if their trip required transferring between two Muni vehicles, with and without a real-time prediction of the connection time. Respondents could choose whether they would take Muni all the way, take Muni until the transfer point and then find another transit mode to their destination, call a TNC or use a taxi. Providing transfer time predictions (assuming a hypothetical 6-minute wait) boosted the percentage of respondents who would take Muni for at least the first portion of their trip from 75 to 90 percent and for the entire length of their trip from 48 to 83 percent.

Crowding

State-of-the-art Automatic Passenger Counters installed on all buses and light rail vehicles purchased after 2014 give the SFMTA the technical ability to report ridership loads and crowding alerts in real time through its new radio communications system. To determine whether such information would be useful, the survey asked what customers would do if the countdown sign showed that a full vehicle would be arriving in 2 minutes followed by vehicle with space available in 6 minutes. In addition, the survey asked participants why they made their choice in an open-ended question.

While 65 percent chose to wait for the following vehicle, 25 percent opted to try to board the first vehicle despite it being full. In open-ended responses, customers explained that they chose the first vehicle because they did not have time to wait for the second vehicle or lacked confidence in the predictions. Many respondents felt the second vehicle would not arrive in the predicted 6 minutes, would have filled up before reaching their stop, or would have to turn back before the end of the line. While they might have felt less comfortable on the first vehicle, at least their departure was guaranteed. The extra 4-minute wait represented an additional time investment, which would leave customers feeling "burned" if the second vehicle failed expectations. Considering this feedback, the SFMTA will conduct further research to explore how best to present vehicle occupancy information.

Deterrents to Transit Ridership and How the Project Would Address Them

Finally, SFMTA's survey asked customers to recall the last time they chose another form of transportation over Muni, and to select up to two factors that influenced their decision. As shown in Figure 12, the majority of responses identified service-related factors. The Next Generation Customer Information System could mitigate some of these factors and turn negative experiences into neutral or even positive ones. Over the long term, improved customer satisfaction would translate into ridership retention and growth.

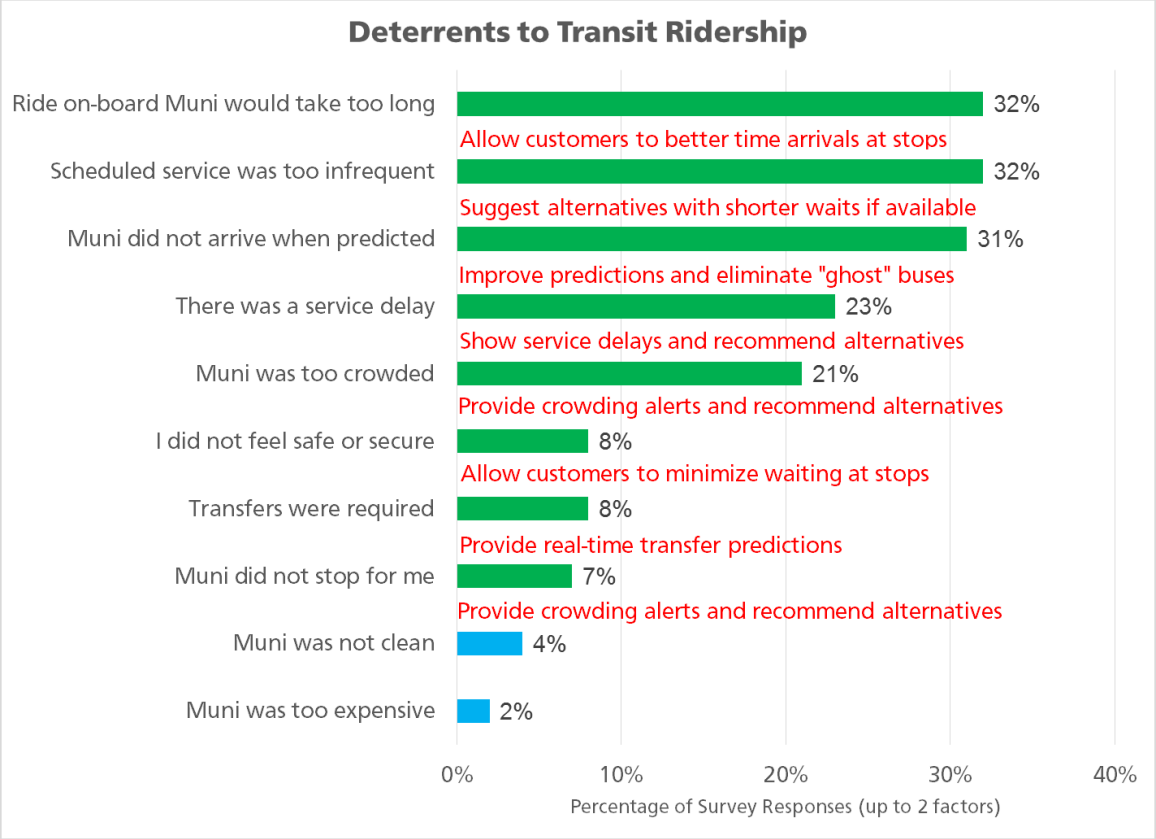


Figure 12: Deterrents to Transit Ridership and How the Project Would Address Them

INNOVATIONS

Based on what the SFMTA learned from its public outreach initiative, the Next Generation Customer Information System must provide accurate, context-sensitive and comprehensive data for Muni to compete with other transportation options. Therefore, the new system will focus on improving prediction accuracy, keeping customers continually informed, retaining those who might otherwise use less sustainable transportation modes, and using data analytics to improve service and operational planning.

Examples of innovations include:

- Employing a more sophisticated and accurate vehicle arrival predictions
- Implementing alternatively-powered signage at unpowered shelters and stops to expand customer access to information
- Reducing travel times by showing nearby alternative routes with shorter waits on digital signage at stops
- Communicating service delays and disruptions on-board vehicles
- Balancing capacity by providing crowding alerts and suggesting parallel services with space available
- Strengthening network connectivity by showing transfer times on-board vehicles
- Providing real-time stop and route accessibility information (e.g., elevator/escalator outage alerts) to facilitate travel for seniors and persons with disabilities
- Improving the rider experience via an enhanced mobile platform
- Using data to better understand customer preferences and improve service and operational planning

CONCLUSION

In the new millennium, San Francisco has emerged as a real-life laboratory to explore how technology can radically alter the transportation landscape. Two decades ago, this high-tech hub helped revolutionize the transit riding experience by informing customers when their vehicle was coming in real time. Yet this first-generation real-time transit information system has unfortunately remained relatively static. Today, San Francisco residents and visitors seemingly have more transportation options than ever – and consumer expectations have grown.

SFMTA's Next Generation Customer Information System must adapt to this reality. Traditional demand and mode choice models must also evolve in response to new transportation options. San Francisco is fortunate that Muni still attracts a ridership base representative of its ethnic and socioeconomic diversity. However, the project team's research findings suggest that the status quo could intensify inequities by dividing transportation services into two income-based systems. Losing transit customers to private or ride-hailed automobiles could lead to a downward spiral: Muni could become slower and less attractive as TNC-induced traffic congestion increases, while less fare revenue due to lower ridership could lead to service cuts and fare increases.

With these challenges also come opportunities. Using public input, the project will focus on improving prediction accuracy, keeping customers informed throughout their journey particularly with respect to service disruptions and transfers, leveraging mobile technology and offering alternatives and other supplementary information. This outreach has affirmed that real-time information at the right times and places could potentially increase transit ridership across all demographics, leading to a more equitable and sustainable transportation system. Moreover, it will broaden transit's constituency and deepen public support for system investments that benefit all customers, including historically-disadvantaged populations.

It is SFMTA's hope that the lessons learned from implementing the Next Generation Customer Information System will in turn help other transit systems prepare for the future.

APPENDIX – STAKEHOLDERS ENGAGED

311
Access SFUSD
American Public Transportation Association
BART
Better Market Street
Building Owners and Managers Association of San Francisco
Chinatown Community Development Center (CCDC)
CivicMakers
Conduent
EMPOWER
Hotel Council
Independent Living Resource Center of San Francisco
LightHouse for the Blind and Visually Impaired
Mayor's Office of Disability
Mayor's Office of Neighborhood Services
Mercy Housing
Northwest Transit Exchange
Paratransit
Rail~Volution
Rebuild Potrero
San Francisco Board of Supervisors
San Francisco Mayor's Office
San Francisco Transit Riders
SaveMuni
Senior & Disability Action Network
SF Travel
SFMTA Board of Directors
SFMTA Citizens' Advisory Council
SFMTA Multimodal Accessibility Advisory Committee (MAAC)
SFMTA Policy and Governance (PAG)
SPUR
The Public Voice
TransitCenter
Transbay Joint Powers Authority
Transit Riders Union
Transportation Research Board
UCSF Parnassus
Youth Commission

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