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DEMAND-RESPONSIVE TRANSIT SHUTTLES: WHO WILL USE THEM?

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ABSTRACT
Large urban areas often have rail systems that rely on feeder buses to expand their service area. This paper explores the possibility of expanding access to existing rail transit systems through demand-responsive shuttles. The study analyzes the effect of several factors on an individual's willingness to use a door-to-station shuttle service. Using survey data collected in a case study of one urban and one suburban neighborhood (N=800) served by the San Francisco Bay Area Rapid Transit, this paper uses descriptive statistics and ordered logit regression to investigate the influence of several factors on peoples' willingness to use the shuttles. The results indicate that 21% of the respondents were strongly inclined to at least trying the service and paying for it. Residents of the urban neighborhood and those who lived more than half a mile from the nearest transit station were more willing to use the shuttle. Interestingly, 20% of single-occupant automobile users in both the urban and suburban communities were highly willing to use the shuttle, if only on a trial basis. Furthermore, those who park-and-ride in the suburban neighborhood and those who carpool or ride transit in the urban neighborhood were most likely to try the proposed shuttle service.

Keywords—Public transit, shuttles, traveler behavior, Bay Area Rapid Transit

Executive Summary

Large urban areas often have rail systems that rely on feeder buses to expand their service area. This paper explores the possibility of expanding access to existing rail transit systems through demand-responsive shuttles. The study analyzes the effect of several factors on an individual's willingness to use a door-to-station shuttle service. Using survey data collected in a case study of one urban and one suburban neighborhood (N=800) served by the San Francisco Bay Area Rapid Transit, this paper uses descriptive statistics and ordered logit regression to investigate the influence of several factors on peoples' willingness to use the shuttles.

To design the study we selected the Castro Valley and Glen Park neighborhoods in San Francisco, based on several criteria. The two study areas are similar in that they are relatively underserved by rail, have hilly neighborhoods with winding streets, and are populated by middle and upper-middle income households. The key difference is that Glen Park is located in an urban setting while Castro Valley is located in a suburban setting. Homes in Glen Park are typically older row houses while in Castro Valley they are newer and more spread out. This made it possible to study the behavioral differences related to the shuttle service between urban and suburban neighborhoods.

In the survey, respondents were asked how likely they were to use the shuttle service to get to and from the transit station, if the service cost what they are willing to pay and has acceptable wait, trip-length, and scheduling times. The possible outcomes were 1 (not at all willing) to 5 (very willing), with a few respondents indicating that they were unsure. The survey indicates that there is a moderate willingness to use shuttles in both urban and suburban neighborhoods. Approximately 35% of respondents reported that they were 'not at all willing' to use a shuttle, though approximately 20% reported that they were 'very willing' to use a shuttle. It should *not* be interpreted that 20% of the respondents will permanently shift from their current mode of travel to demand-response transit shuttles. Indeed, mode shift of this magnitude cannot be expected since mode choice is a long-term decision based on the perceived utility of each mode. At most, it can be expected that these respondents will use a shuttle on a trial basis, after which time they will decide if it's utility is higher than that of the alternatives.

On average, suburbanites are willing to pay more for shuttle service. Similarly, on average the maximum time that an individual is willing to wait for a shuttle is greater in suburban communities. This may reflect the greater transportation alternatives available to urbanites. Over 40% of the respondents were not at all willing to pay or wait for a shuttle. Still, 10% were willing to pay the maximum fare level ($5) and 20% were willing to wait the maximum time level (20 minutes).

It is important to quantify the percentage of people that are willing to switch to the shuttle, whether this is a one-time event or a permanent shift. The modes that are 'very willing' to use the shuttle in urban settings are car (19.9), carpool (25.0), and transit (23.4) percent, while in suburban settings the modes that are 'very willing' to use the shuttle are park-and-ride (42.9), carpool (21.2), car (19.9) and transit (17.2) percent. This indicates that shuttles can be targeted to suburban park-and-ride users, though since this group typically comprises only a small portion of the transportation mode share, the overall impact may be small. Interestingly, a large portion of the auto users (20%) were willing to try the shuttle service in both urban and suburban San Francisco neighborhoods. Given that BART is real alternative to automobile travel in San Francisco, partly due to relatively high levels of the service and coverage and the high levels of traffic congestion and high costs of travel (parking and tolls, etc.), it is not surprising that such a

large number of auto users expressed a willingness to try to the shuttle service. Targeting this relatively large group for the shuttle service can have a large overall impact on the transportation system. In urban neighborhoods, transit agencies will have the most success at getting carpool and transit users to try the shuttle.

To get a better sense of the effect of each of the variables we used marginal effects of the dependent variable with respect to each of the independent variables. The marginal effects show the percentage change in the probability a respondent will report each of the possible outcomes of the dependent variable, given a one-unit change in the independent variable and allow us to analyze the effects of each independent variable at all possible values on the dependent variable.

The distance an individual lives from the nearest transit station is the single most important factor at predicting their willingness to use a shuttle. In general, those who live closest to the station are the most willing to use it. Individuals who live within 0.25 and between 0.25 and 0.50 miles of the nearest transit station are 8.6% and 7.3% less likely to be 'very willing' to use a shuttle. This result is conceptually sound, since the walkable distance to a transit station is typically considered to be less than 0.5 miles. The greater the numbers of vehicles per household, the less willing individuals are to use a shuttle. Each additional vehicle owned reduces the chance that they will be 'very willing' to use the shuttle by 1.7% and increases the chance that they will be 'not at all willing' to use the shuttle by 3.6%. Urbanites have a 2.4% greater chance to be 'very willing' to use the shuttle than suburbanites. This probably reflects the greater congestion and grid road network in urban areas.

As was expected, the greater one's willingness to wait and pay for a shuttle is associated with their willingness to use a shuttle—though this effect is likely to be non-causal. That is, there is endogeneity (circularity) between willingness to use and pay. Those who are most willing to use a shuttle are most prepared to pay more and wait longer for it. Those that are 'not at all willing' to use the shuttle would not want to pay for it at any cost nor would they want to wait for it to pick them up. Each additional $5 cost of the shuttle service is associated with reduced chances that an individual will be 'not at all likely' to use a shuttle by 7.4% and higher chance that they will be 'very willing' to use a shuttle by 3.4%. Similarly, each additional 5 minutes of time spent waiting for a shuttle is associated with reduced chances that individuals will be not at all willing to use a shuttle by 3.3% and higher chances that they will be very willing to use a shuttle by 1.5%.

Minorities that include Latinos, Asians and African-Americans are less willing to use shuttles than whites. Interestingly, African-Americans are least willing to use shuttles (5.7% less than whites), followed by Latinos (3.7%) and Asians (1.0%), the exact opposite of what has been found in studies of other public transportation modes. Similarly, lower income households are less willing to use the shuttle than higher income households. Low-income households (<$30,000 annually) are 4.7% less likely to be 'very willing' to use a shuttle than high-income households (>$100,000 annually). They are 13.5% more likely to be 'not at all willing' to use a shuttle than high-income households.

The purpose of this paper was to investigate whether transit agencies can expand their service to underserved areas and who will use the service. First, it sought to analyze which transportation modes are most likely to switch to the proposed shuttle service, even if on a trial basis. It found that demand-responsive transit shuttles can most successfully be targeted to park-and-ride users in urban communities. Forty percent of the respondents in this group indicated that they would be willing to try the shuttle. This could provide significant congestion reduction at park-and-ride lots. Interestingly, a large portion of the single-occupant automobile users (nearly 20%) were very willing to try the service in both neighborhoods. Targeting this group can be very beneficial from the transit agency's perspective, in terms of increasing coverage and ridership and from the transportation system's perspective in terms of performance improvement. Second, the paper rigorously analyzed the factors that influence willingness to use a shuttle. Higher willingness to use the shuttle was associated with longer distances from the nearest transit station, higher stated willingness to pay and willingness to wait for the shuttle and residence in an urban community. Older people and people with more vehicles were less inclined to trying/using the shuttle. Surprisingly, groups that traditionally have a higher propensity to use public transportation, e.g., some minority groups, and lower-income individuals were less willing to use the proposed shuttle than non-minorities and higher-income households. This could be partly due to the shuttle perceived as a higher-end service. Overall, the study finds that a consumer-based shuttle service might be feasible, given that 21% of the respondents expressed a strong interest in using the service and also paying for it. Based on this, it will be interesting to look at the possibility of a greater private sector role in fully or partially providing such a service.

Compared to other cities, San Francisco is somewhat unique in terms of population, openness to innovations and geography. The issues investigated in this study are context-specific and may not generalize to other cities. Still, this study clearly suggests that public transportation planners in other (similar) large metropolitan areas explore and evaluate expanding transit service to underserved urban areas via shuttles.

INTRODUCTION

Traditional transit systems in the United States evolved in response to the explosion of suburban development after World War II. They are characterized by transit routes that resemble radial spokes of a wheel, linking residential areas in the suburbs to commercial districts in the city. Since density in these suburbs tends to be low, residents have limited access to transit stations. Most live beyond the ¼ mile ‘service area’ of the station. The minority of commuters who do not find it easier to drive to their destinations often compete for scarce park and ride spaces, walk, or take transit to the station. In order to encourage more residents to ride transit, it has become necessary for transit agencies to expand the services they offer to make transit more accessible (1). One method that transit agencies are increasingly utilizing is demand responsive shuttle service. Commuters reserve a seat on a shuttle that collects them at their home and transports them to a local transit station for a fee.

The purpose of this study is twofold. First, it will evaluate the potential market penetration of demand-responsive transit shuttle service and investigate the extent to which shuttles can expand a transit agency’s service area to travelers located outside of the station’s vicinity. Second, it will analyze the factors that influence riders’ willingness to use and pay for the shuttles. Using the San Francisco’s Bay Area Rapid Transit (BART) shuttle as a case study, this paper reports results that can be valuable to other (similar) transit agencies.

LITERATURE REVIEW

This literature review covers three areas of Demand Responsive Transit (DRT) research: 1) factors that influence transit use, 2) Advanced Public Transportation Systems (APTS), and 3) integrating DRT with fixed-route transit service.

Several articles address the need for demand responsive transit. Moore (2) concludes that as job creation is increasingly concentrated in the suburbs, more demand responsive transit services need to be made available. In the suburbs, most commuters live farther than ¼ mile from a transit node, the maximum distance that the average passenger will walk. With limited parking availability at these nodes, one method of increasing transit ridership is to provide public transportation to areas located further than ¼ mile from the station (2). Cervero investigates flextime work schedules as one method that employers can use to increase commuters propensity to use transit (3).

Several factors are likely to influence a passenger’s willingness to use DRT. Flannelly et al. (4) found that enhanced service is an important incentive for attracting automobile users to use DRT, including reduced time spent walking to pick-up/drop-off points, and guaranteed seating. A charge of $6 for parking in the Portland, Oregon CBD will result in a 21% drop in driving alone. The results suggest that parking fees can increase transit’s modal share significantly (4, 5). Taylor et al. found that increasing parking fees is more likely to encourage transit usage than expanded transit service. Taylor et al. (6) also found that reducing fare cost and expanding service area would increase ridership.

Yim et al (7) found that 17% of passengers are ‘very likely’ to use on-demand DRT and that 15% are ‘very likely’ to use fixed-schedule shuttle services. An additional 12% and 14% are ‘likely’ to use these services. If their desired trip length needs and cost are met, 21% and 22% of users are ‘very likely’ to use DRT.

For years, demand-responsive transit shuttles mostly served the elderly and disabled. The excessive cost of shuttles, the inability to maintain a tight schedule, and the difficulty of coordinating shuttle routes made shuttles a poor alternative to other modes of transportation.

Recently, demand responsive transit (DRT) has become a feasible alternative due to technologies such as Advanced Public Transportation Systems (APTS) that can increase the efficiency of transit vehicles, improving the level of service, and reducing costs. In a survey of 40 APTS technology providers, Khattak found that innovations such as Automatic Vehicle Location (AVL) and Computer Aided Dispatch (CAD) can increase transit ridership share by increasing the efficiency of transit vehicles, improving the level of service, and reducing costs. Users can benefit from reduced travel and wait times and increased security (8, 9). In two studies, Teal found that many of the early problems of DRT were due to technologies that were not cost-effective. APTS technologies are only cost-effective when scheduling is done in advance. The growing sophistication of 'affordable' APTS technologies can make DRT much more efficient (10, 11).

Many transit agencies are considering integrating DRT with traditional, fixed-route service. The potential impacts of this are increased ridership and greater accessibility in low-density areas, reduced operation costs by conducting one leg of a trip on DRT, and meeting ADA requirements by providing DRT service to the elderly and disabled.

Integrating DRT with fixed-route service creates a problem of scheduling both passenger and transit trips, as existing software are not sufficiently sophisticated to do this. Three studies attempted to develop a method to integrate DRT with fixed-route service. Wilson's model (12) integrates DRT service with fixed-route service without considering the costs incurred by the transit agency. Liaw's model (13) considers the costs of scheduling passengers and vehicle trips, but does not address the level of service requirements of passengers. Hickman et al (14) build on the previous models by considering both passenger level of service and transit agency cost. They find that 26% of DRT-only trips in Houston could be substituted with integrated DRT/fixed-route trips. This would reduce METROLift's operating costs by 15%.

Because transit often involves several transportation modes, travel times on transit are often greater than travel times in a single-occupant vehicle and could predict which individuals are likely to shuttles. The value that individuals associate with time depends on several factors, including the purpose of the trip (business, non-business) and the specific characteristics of the trip-maker, e.g., income (15).

METHODOLOGY

To design the study we selected the Castro Valley and Glen Park neighborhoods in San Francisco, based on several criteria. The two study areas are similar in that they are relatively underserved by rail, have hilly neighborhoods with winding streets, and are populated by middle and upper-middle income households. The key difference is that Glen Park is located in an urban setting while Castro Valley is located in a suburban setting. Homes in Glen Park are typically older row houses while in Castro Valley they are newer and more spread out. This made it possible to study the behavioral differences related to the shuttle service between urban and suburban neighborhoods.

The Survey

A demand-responsive transit shuttle survey was conducted in October 2001 by Computer-Aided Telephone Interview (CATI) in the two selected neighborhoods. The survey was randomly given to 400 individuals living in the suburban neighborhood surrounding the Castro Valley transit station and 400 residents living in the urban neighborhood surrounding the Glen Park station (Figure 1). The survey was conducted by random digit dialing. Respondents were required to be at least 18 years old, with no more than 52% female and 48% male (the Bay Area male and female ratio).

Each respondent was asked information about their typical trip at the beginning of the survey and socioeconomic characteristics at the end. The survey uses skip patterns to find out the conditions under which respondents would be willing to use the shuttle. For example, only those respondents who indicate that they have some level of interest in the shuttle (even if minimal) are asked about their maximum willingness to pay for and wait for the shuttle, and willingness to use the shuttle. Those respondents that have no interest in the shuttle skip the body of the survey and go to the socioeconomic section. Of a survey size of 800 respondents, 532 were at least minimally interested in the shuttle service and were asked about their willingness to use the shuttle under several scenarios, including varying costs and wait times.

Figure 2 illustrates the structure of the survey. In order to compare the behavioral differences between suburban and urban communities, the survey structure is separated by neighborhood. The transportation mode a respondent usually uses indicates the preferred mode choice for all 400 respondents in each study area. These include both commute and non-commute trips. The mode of public transit a respondent uses indicates the transit mode that commuters whose preferred mode choice is transit (including park-and-ride) use.

Analytical Methods

Univariate, bivariate, and multivariate statistics will be used in this analysis. Univariate statistics include measures of central tendency and measures of dispersion in order to analyze the distribution of data values. Bivariate statistics are used to determine if statistically significant relationship exists between the independent variables and the dependent variable. Multivariate statistics are used to measure the overall significance of the models.

Two separate analyses are conducted in this study. First, the paper quantifies the percentage of each mode share that can be expected to use demand-responsive transit shuttles, even if it is only on a trial basis. This is calculated using cross-tabulations of revealed mode choice and stated willingness to use the shuttle. The second analysis includes several parts. First, hypothesized relationships between the independent and dependent variables are presented. Second, an ordered logit model is used to indicate which independent variables are significant and the direction of their effect on the dependent variable. Finally, the marginal effects are presented to show the percentage change in the probability a respondent will report each level of willingness to use the shuttle, given a unit change in the independent variable.

The shuttle survey uses skip patterns. Answers to questions determine the following questions that will be asked. For example, 123 of 800 respondents were asked the distance their residence is located from the nearest transit station. In this case, missing values were coded as a zero to increase the sample size for model estimation. A separate dummy variable was created that coded missing values for the variable as one and zero for all answered. Both variables are then used in the model specification. For the income variables, many respondents refused to answer, and so the appropriate measure of central tendency were used to fill in the missing values.

Hypothesized Relationships

There are several factors that may affect a traveler's willingness to use shuttles. Hypothesized relationships for each of the explanatory variables are presented based on the reviewed literature and theory. Willingness to pay (WTP) and willingness to wait (WTW) indicate the maximum a traveler is willing to pay and the maximum time a traveler is willing to wait for a shuttle. WTP and WTW will have a positive relationship with willingness to use a shuttle, partly due to self-selection. Those who indicate that they are most willing to use a shuttle are willing to pay more and willing to wait longer for a shuttle. Conversely, those who will be less willing to use the shuttle are likely not willing to pay or wait for it. Importantly, there is circularity between these variables and unidirectional causality cannot be assumed. Individuals who live in urban neighborhoods will be more willing to use the shuttle service due to the transit pre-disposition of people living denser areas and relatively high levels of traffic congestion.

Households with more vehicles are typically less likely to use public transit. Since auto ownership requires a high initial cost, those who own automobiles tend to use them. Though demand-responsive transit shuttles are not a traditional form of public transportation, it is still reasonable to assume that the more vehicles a household owns, the less likely they will be to use a shuttle. The effect of income on willingness to use a shuttle will be negative. The greater a person's income, the less likely they are to use transit or a demand-responsive transit shuttle to access it. Similarly, African-American, Latinos and Asians are perhaps more likely to use shuttles than whites. Individuals who park-and-ride will be more willing to use the shuttles. Since park-and-ride entails at least one leg of the trip on transit, these individuals will be more willing to use the shuttle. Local factors such as unavailability of spaces in Park-and-Ride lots may encourage some to use the shuttle. Those who have access to a car and use it to get to their destination will be less willing to use a shuttle. The relationship between carpooling and willing to use a shuttle is harder to hypothesize.

THE CONTEXT

Table 1 summarizes the demographics for the two study areas and provides characteristics of Castro Valley and Glen Park. Castro Valley is located 27 miles southeast of San Francisco, across the San Francisco Bay, and 13 miles south of Oakland. The Castro Valley study area has a population of 282,133, and at 62.1 square miles, has a density of 4,543 people per square mile. The survey over-represents whites and older residents. The following differences between the survey and the 2000 census exist and are expressed as survey data followed by census data in parenthesis. The racial composition is approximately 52.8 (75.4) percent white, 10.4 (4.1) percent black, and 15.3 (11.2) percent Asian while the average age is 35.1 (49.3) years and the average household size is 2.9 (2.8) people. The road design roughly follows a grid pattern with cul-de-sacs.

Glen Park is located approximately three miles from downtown San Francisco, on the city's southern border. The population for the Glen Park survey area is 236,265, with 15.9 square miles and a density of 17,744 people per square mile. Whites, older residents and smaller households are over represented. The racial distribution for the census (survey) was 41.9 (70.5) percent white, 6.7 (4.7) percent black, and 30.7 (12.7) percent Asian. The average age was 36.5 (46.7) years and the average household size was 3.03 (2.53).

The median distance a survey respondent lives from the nearest transit station is greater in Castro Valley than in Glen Park, as expected. The average respondent in Glen Parks lives 7 to 8 blocks from the station while in Castro Valley the median distance is 1 to 2 miles. Castro Valley respondents have nearly 40% more cars per household than their Glen Park counterparts. This is logical, since on average, Castro Valley respondents live further from the nearest station than do their counterparts in Glen Park, and so have a greater reliance on automobiles to transport them to either their end destination, or to the transit station. The before tax income level in Glen Park is greater than in Castro Valley. In Glen Park the median income level was between \$70,000 and \$79,999. In Castro Valley the median income level was \$60,000 to \$69,999.

The survey further illustrates the context (Figure 2). The percentage of respondents who indicated that they were transit riders was greater in the urban community (35.3%) of Glen Park than in the suburban community (7.3%) of Castro Valley. However, in both study areas, the majority of respondents were car users (56.5% in the urban neighborhood and 80.3% in the suburban neighborhood). Of those commuters who reported that they usually ride transit (including park-and-ride), a similar percentage of both urban (62.3%) and suburban (67.4%) commuters rode rail. The modes that commuters used to get to the transit station vary and reflect the demographics, density, and road design of the two neighborhoods. The majority of urban rail commuters (58.5%) walk to the transit station while the majority of suburban rail commuters (72.4%) arrive at the station by car.

DESCRIPTIVE RESULTS

In the survey, respondents were asked how likely they were to use the shuttle service to get to and from the transit station, if the service cost what they are willing to pay and has acceptable wait, trip-length, and scheduling times. The possible outcomes were 1 (not at all willing) to 5 (very willing), with a few respondents indicating that they were unsure. The survey indicates that there is a moderate willingness to use shuttles in both urban and suburban neighborhoods. Approximately 35% of respondents reported that they were 'not at all willing' to use a shuttle, though approximately 20% reported that they were 'very willing' to use a shuttle (see Figure 3). It should *not* be interpreted that 20% of the respondents will permanently shift from their current mode of travel to demand-responsive transit shuttles. Indeed, mode shift of this magnitude cannot be expected since mode choice is a long-term decision based on the perceived utility of each mode. At most, it can be expected that these respondents will use a shuttle on a trial basis, after which time they will decide if it's utility is higher than that of the alternatives.

On average, suburbanites are willing to pay more for shuttle service. Similarly, on average the maximum time that an individual is willing to wait for a shuttle is greater in suburban communities. This may reflect the greater transportation alternatives available to urbanites. Over 40% of the respondents were not at all willing to pay or wait for a shuttle. Still, 10% were willing to pay the maximum fare level (\$5) and 20% were willing to wait the maximum time level (20 minutes) (see Figures 4 and 5).

It is important to quantify the percentage of people that are willing to switch to the shuttle, even if it is on a trial basis. Table 2 indicates that the modes that are 'very willing' to use the shuttle in urban settings are car (19.9), carpool (25.0), and transit (23.4) percent, while in suburban settings the modes that are 'very willing' to use the shuttle are park-and-ride (42.9), carpool (21.2), car (19.9) and transit (17.2) percent. This indicates that shuttles can be targeted to suburban park-and-ride users, though since this group typically comprises only a small portion of the transportation mode share, the overall impact may be small. Interestingly, a large portion of the auto users (20%) were willing to try the shuttle service in both urban and suburban San Francisco neighborhoods. Given that BART is real alternative to automobile travel in San Francisco, partly due to relatively high levels of the service and coverage and the high levels of traffic congestion and high costs of travel (parking and tolls, etc.), it is not surprising that such a large number of auto users expressed a willingness to try to the shuttle service. Targeting this relatively large group for the shuttle service can have a large overall impact on the transportation system. In urban neighborhoods, transit agencies will have the most success at getting carpool and transit users to try the shuttle.

MODEL RESULTS

In Model 1, 19 independent variables are used, comprising contextual and socioeconomic variables (Table 3). The model combines revealed and stated preference data. Though three of the variables related to revealed mode choice were statistically insignificant (90% confidence level) and were removed in Model 2. Both models are significant overall as indicated by the Chi-squared significance levels and their fits are reasonable. Several variables are notable. In particular, Glen Park residents are more likely (with 90% confidence level) to state a willingness to use the shuttle. This is in line with our expectation of urban, rather than suburban, residents being more willing to use the shuttle due to their transit pre-disposition and relatively higher levels of traffic congestion. Higher willingness to use the shuttle is also associated with longer distances from the nearest BART station, higher stated willingness to pay and willingness to wait for the shuttle. Older people and people with more vehicles were less inclined to trying/using the shuttle. Furthermore, income exerts a positive influence on willingness to use the shuttle service, i.e., higher income respondents are more willing to try the service. Additionally, minority status has a negative effect on willingness to use the shuttle, with African-American the least willing to use the shuttle at least in these neighborhoods. Other ethnicities, including Asians and Latinos were not statistically different from Whites in terms of their disposition to shuttle use.

To get a better sense of the effect of each of the variables, Table 4 provides the marginal effects of the dependent variable with respect to each of the independent variables. The marginal effects show the percentage change in the probability a respondent will report each of the possible outcomes, given a one-unit change in the independent variable. The sum of the marginal effects must equal zero, with the highest and lowest value of opposite signs. The possible outcomes for the dependent variable, willingness to use the shuttle, range from 1 (not at all willing) to 5 (very willing). The marginal effects allow us to analyze the effects of each independent variable at all possible values on the dependent variable.

The distance an individual lives from the nearest transit station is the single most important factor at predicting their willingness to use a shuttle. In general, those who live closest to the station are the most willing to use it. Individuals who live within 0.25 and between 0.25 and 0.50 miles of the nearest transit station are 8.6% and 7.3% less likely to be ‘very willing’ to use a shuttle. This result is conceptually sound, since the walkable distance to a transit station is typically considered to be less than 0.5 miles.

The greater the numbers of vehicles per household, the less willing individuals are to use a shuttle. Each additional vehicle owned reduces the chance that they will be ‘very willing’ to use the shuttle by 1.7% and increases the chance that they will be ‘not at all willing’ to use the shuttle by 3.6%. Urbanites have a 2.4% greater chance to be ‘very willing’ to use the shuttle than suburbanites. This probably reflects the greater congestion and grid road network in urban areas.

As was expected, the greater one’s willingness to wait and pay for a shuttle was associated with their willingness to use a shuttle. Those who are most willing to use a shuttle are most prepared to pay more and wait longer for it (and vice-versa). Those that are ‘not at all willing’ to use the shuttle would not want to pay for it at any cost nor would they want to wait for it to pick them up. ach additional $5 cost of the shuttle service is associated with reduced chances that an individual will be ‘not at all likely’ to use a shuttle by 7.4% and higher chance that they will be ‘very willing’ to use a shuttle by 3.4%. Similarly, each additional 5 minutes of time spent waiting for a shuttle is associated with reduced chances that individuals will be not at all willing to use a shuttle by 3.3% and higher chances that they will be very willing to use a shuttle by 1.5%. These results cannot be interpreted literally because there is endogeneity and perhaps self-selection. Those most willing to use a shuttle will be willing to wait longer for it and those who are less willing to use it will willing to pay less for it.

Respondents over age 55 are 3.0% less likely to be 'very willing' to use a shuttle and 7.0% more likely to be 'not at all willing' to use a shuttle than their younger counterparts.

Minorities are less willing to use shuttles than whites. Interestingly, African-Americans are least willing to use shuttles (5.7% less than whites), followed by Latinos (3.7%) and Asians (1.0%), the exact opposite of what has been found in studies of other public transportation modes. This could be due to the phrasing of the survey that portrays shuttle service as a high-end public transportation mode, unlike more traditional access modes, such as buses. The survey asks the respondent to suppose that the 'service would use comfortable, air-conditioned vans and pick-ups would be scheduled for convenient times throughout the day and would be coordinated with the…train.' Similarly, lower income households are less willing to use the shuttle than higher income households. Low-income households (<$30,000 annually) are 4.7% less likely to be 'very willing' to use a shuttle than high-income households (>$100,000 annually). They are 13.5% more likely to be 'not at all willing' to use a shuttle than high-income households.

Limitations

There are several limitations of this analysis. First, this paper sought to quantify the percentage of each mode share that can be expected to use the shuttle. Due to the nature of the survey, use of the shuttle could range from a one-time event to a permanent switch to the shuttle from the respondent's current mode. Mode choice is a long-term decision based on the utility of alternatives. Individuals may underestimate or not consider some of the constraints of shuttles and realize after a trial period that it is not appropriate for their lifestyle. Second, some of the results seem counterintuitive. Contrary to the findings of other studies, minorities and lower income households tend to be those groups that have higher rates of transit usage. While demand responsive shuttles are not traditional public transportation, the phrasing on several of the questions may have led respondents to assume that the proposed shuttles are a higher-end service. Third, due to the skip patterns in the survey, the sample size for some of the variables was small. To circumvent this problem, new variables were created. Finally, response bias may also be a limitation. Despite the limitations, the survey was implemented professionally using the CATI technique, it reasonably represents the resident population of the neighborhoods, there was very little missing data (beyond the skip patterns) and the descriptive statistics and model results are reasonable.

CONCLUSIONS

The purpose of this paper was to investigate whether transit agencies can expand their service to relatively underserved areas and who will use the service. Using a behavioral survey in two San Francisco neighborhoods, this study attempted to answer this question in two ways. First, it sought to analyze which transportation modes are most likely to switch to the proposed demand-responsive shuttle service, even if on a trial basis. It found that demand-responsive transit shuttles can most successfully be targeted to park-and-ride users in urban communities. Forty percent of the respondents in this group indicated that they would be willing to try the shuttle. This could provide significant congestion reduction at park-and-ride lots. Interestingly, a large portion of the single-occupant automobile users (nearly 20%) were very willing to try the service in both neighborhoods. Targeting this group can be very beneficial from the transit agency's perspective, in terms of increasing coverage and ridership and from the transportation system's perspective in terms of performance improvement. Second, the paper rigorously analyzed the factors that influence willingness to use a shuttle. Higher willingness to use the shuttle was associated with longer distances from the nearest transit station, higher stated willingness to pay and willingness to wait for the shuttle and residence in an urban community. Older people and people with more vehicles were less inclined to trying/using the shuttle. Surprisingly, groups that traditionally have a higher propensity to use public transportation, e.g., some minority groups, and lower-income individuals were less willing to use the proposed shuttle than non-minorities and higher-income households. This could be partly due to the shuttle perceived as a higher-end service. Overall, the study finds that a consumer-based shuttle service might be feasible, given that 21% of the respondents expressed a strong interest in using the service and also paying for it. Based on this, it will be interesting to look at the possibility of a greater private sector role in fully or partially providing such a service.

Compared to other cities, San Francisco is somewhat unique in terms of population, openness to innovations and geography. The issues investigated in this study are context-specific and may not generalize to other cities. Still, this study clearly suggests that public transportation planners in other (similar) large metropolitan areas explore and evaluate expanding transit service to underserved urban areas via shuttles.

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FIGURE 1: Glen Park and Castro Valley study areas

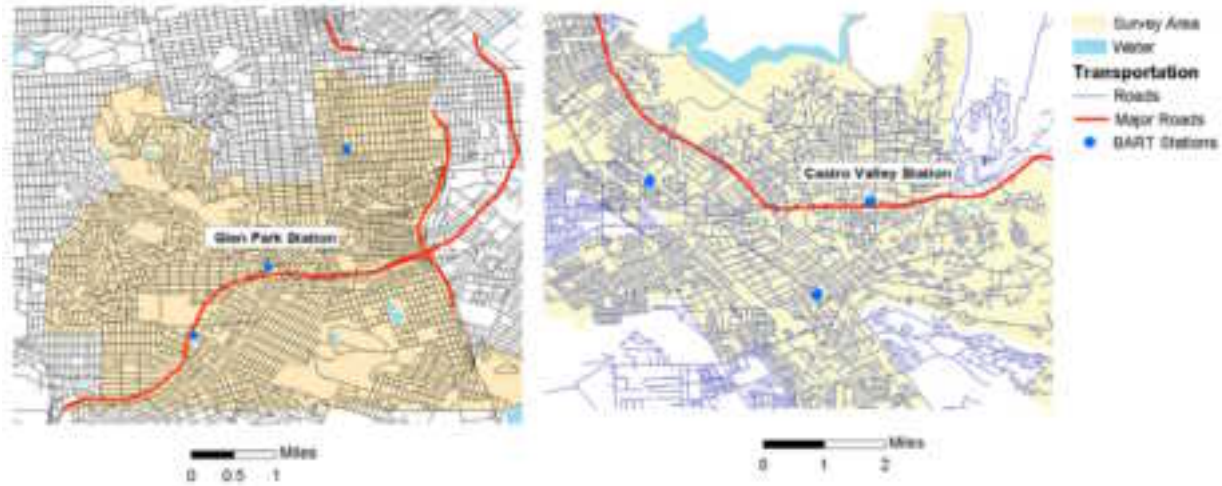

FIGURE 2: BART Shuttle Survey Structure

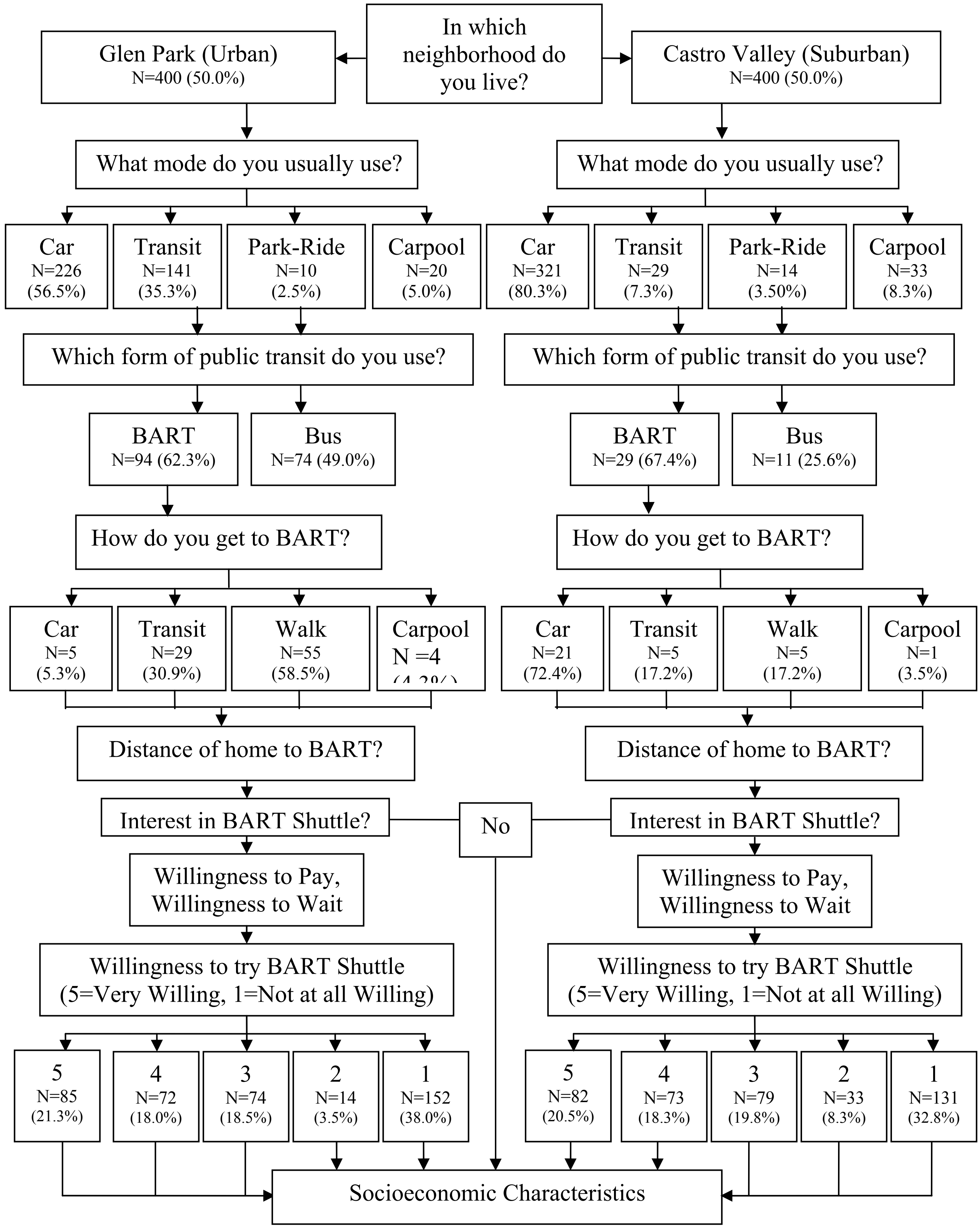

TABLE 1: Summary Statistics of Castro Valley and Glen Park[1]

Demographics	Castro Valley		Glen Park	
	Survey	Census	Survey	Census
White (%)	75.4	52.8	70.5	41.9
Black (%)	4.1	10.4	4.7	6.7
Asian (%)	11.2	15.3	12.7	30.7
One or more cars per Household (%)	98.5	--	93.3	--
Average Age	49.3	35.1	46.7	36.5
Average Household Size	2.80	2.85	2.53	3.03
Median family income	$65,000	--	$75,000	--
Low Income Households (%)	10.0	--	12.0	--
Medium Income Households (%)	23.5	--	20.8	--
Medium-high Income Households (%)	43.0	--	42.3	--
High-Income Households (%)	23.5	--	24.9	--
Distance to station is ≤ 0.25 miles (%)	20.7	--	24.5	--
Distance to station is between 0.25 and 0.50 miles (%)	6.9	--	28.7	--

Study Area Characteristics	Castro Valley	Glen Park
Population	282,133	236,265
Area (sq. miles)	62.1	15.9
Density	4,543	17,744
Average Housing Value	$298,300	n/a
Road Design	Grid	Grid/Cul-de-Sac

NOTE: Hyphen indicates data are not available.

TABLE 2: Respondents 'Very Likely' to try the BART Shuttle

Castro Valley

	High stated willingness to try shuttle		All other respondents		Revealed Preferences	
	N	Row %	N	Row %	N	Total %
Single-Occupant Car	64	19.9	257	80.1	321	100.0
Motorcycle	0	0.0	3	100.0	3	100.0
Carpool	7	21.2	26	78.8	33	100.0
Transit	5	17.2	24	82.8	29	100.0
Park-&-Ride	6	42.9	8	57.1	14	100.0
Total	82	20.5	318	79.5	400	100.0

Glen Park

	High stated willingness to try shuttle		All other respondents		Revealed Preferences	
	N	Row %	N	Row %	N	Total %
Single-Occupant Car	45	19.9	181	80.1	226	100.0
Motorcycle	0	0.0	3	100.0	3	100.0
Carpool	5	25.0	15	75.0	20	100.0
Transit	33	23.4	108	76.6	141	100.0
Park-&-Ride	2	20.0	8	80.0	10	100.0
Total	85	21.3	315	78.7	400	100.0