BUILT ENVIRONMENT AND DEMOGRAPHIC PREDICTORS OF BICYCLE ACCESS TO TRANSIT: AN INVESTIGATION IN THE SAN FRANCISCO BAY AREA

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ABSTRACT

Successful integration of bicycle access with transit can help transportation agencies achieve multiple goals. From the agency's perspective, the interface can increase the catchment area of its stations, boosting ridership and increasing transit's competitiveness with the automobile for door-to-door service. From the bicyclist's point of view, integration with transit can help him or her complete trips not otherwise possible because of distance or environmental barriers. While previous research has focused on case studies or qualitative analyses of bike-transit integration, there are few quantitative studies that examine predictive relationships of levels of bicycle access to transit. This study aims to close that gap by considering associations of the built environment and demographic variables with the rates of bicycling to transit stations using an aggregate dataset built from questionnaires administered by the Bay Area Rapid Transit District in the San Francisco Bay Area. Relationships are discovered using a cross-sectional regression analysis of data collected in 2008. The analyses find that some demographic variables are predictors of higher rates of bicycling, but only within the subset of those already bicycling to transit. Built environment variables, such as bicycle parking at the station and intersection density, also predict more bicycling, while on-board bike restrictions predict less bicycling. The findings can help transit agencies develop effective policies that will have a meaningful impact on increasing rates of bicycle access to transit.

INTRODUCTION

One of the greatest potentials for the bicycle as a mode of transportation is in helping transit agencies solve the “last-mile problem”—getting riders from the point of origin to the origin transit station and from the destination transit station to the destination activity. Solving this problem can increase transit ridership by making a transit trip competitive with the private automobile in terms of travel time and door-to-door convenience that could not otherwise be done without integrating the bicycle into the trip. Bike-transit integration can be as simple as providing racks on local buses or as extensive as detailed plans and comprehensive policy that coordinate parking, infrastructure treatments, and local land use planning.

Important questions that transit and regional planning agencies must answer are how to help people to see bike-and-ride as a legitimate means of access and how to accommodate travelers once they have ridden their bikes to the station. Effective planning requires an understanding of what factors influence people to choose the bicycle as their access mode. Though researchers have made some inroads into determining these factors, it remains a question that has not been fully answered. This study attempts to further the knowledge by exploring the influences of built environment, socioeconomic, and policy factors on the rate of bicycle access to transit stations.

To assist in answering the question, survey data collected from ridership questionnaires administered by the Bay Area Rapid Transit (BART) District in the San Francisco Bay Area in California are analyzed. The present study contributes to the literature by adding an empirical analysis, particularly in the American context, of the influences of the built environment characteristics and bike parking amenities on bicycling to transit. The findings conclude that the most significant correlates of bicycle access to transit are availability of secure bike parking at the station and intersection density within the vicinity of the station. On-board bike restrictions during peak ridership periods are also found to be significant deterrents to station access by bike. Socioeconomic characteristics of the riders only emerge as significant when examined among the population subset of bike riders, rather than the broader transit ridership.

LITERATURE REVIEW

The review of the academic literature covers both bicycling as a separate transportation mode as well as bicycle-transit integration.

Bicycling as a transportation mode

The literature on factors associated with and influencing bicycling as a commute mode is growing. To date, at least two literature reviews have been conducted that synthesize previous research on bicycle commuting (*1*, *2*). In general, studies of bicycle travel focus on relationships from a number of different categories: the built environment and spatial characteristics, the natural environment, socioeconomic variables, attitudinal factors, and safety and health (*1*). Comparative case studies of policy implementations are also conducted to examine their broader applicability (*2–4*).

The built environment is one important component of what may predict bicycling rates. Research has shown that higher urban density, shorter commuting distance to work, better public transportation access and more mixed land uses may contribute to higher cycling rates (*4–6*). City or town size may be a factor in that larger urban areas often benefit from greater transportation network connectivity, which can influence more bike use (*7*). Pedestrian and bicycle-friendly neighborhood design is somewhat significantly associated with greater levels of bicycling (*8*). Some research is mixed, however, on whether environmental factors correlate with increased odds of bicycling at all

(*9*).

Infrastructure also plays a role in bicyclist behavior. Bicycle lanes and dedicated infrastructure in addition to bike parking—particularly indoor bike parking with showers—are associated with higher rates of bicycling, especially with respect to transit integration (*2*, *10*). Bicycle lane density has a small but negative elasticity with total vehicle miles traveled (*11*). One study finds that, when riding for utilitarian purposes, participants rode over half of their miles on streets with bike lanes, bike boulevards, or separate paths (*12*). Another finds the presence of bike lanes to be significantly correlated with commuting by bike: each additional mile of bike lane per square mile results in about a one percentage point increase of bicycle commuting (*13*). Akar and Clifton (*14*) also find the converse to be true in that a lack of bike lanes is a deterrent to bicycling. Perception also matters: bicycle ridership is significantly associated with the perception of a good bicycle network as well as with the perception of safety (*15*).

Demographic characteristics is a third category that plays an important role in determining the likelihood of traveling by bicycle. Sex is one such characteristic: most studies find that men cycle more than women and that a larger proportion of female bicyclists is associated with higher levels of bike ridership overall (*1*, *12*, *16*, *17*). Women may value bicycle infrastructure improvements more than men as well (*18*). The literature is less clear on the association of income to rates of bicycling. One study shows that a lower per capita income is conducive to a higher level of bike ridership, but also finds high correlation between income and car ownership (*4*). Another study also finds lower income to be significantly related (*17*); however, others point to findings of higher income as significant predictors of bicycling or no significant relationship at all (*1*, *6*, *13*). The effect of income may be masked by other correlates, such as automobile ownership, education, and age (*1*, *17*). Some studies have also found race and ethnic origin to have significant associations with bicycling. Whites and Hispanics travel by bicycle at about the same rates and significantly more than blacks (*19*). Immigrants are more likely than native-born Americans to travel by bicycle (*20*). One takeaway from the mixed findings of socioeconomic studies is that attitudes and cultural norms may be correlated with demographics and may turn out to be better predictors (*1*).

Perhaps what matters most for increasing cycling rates are not individual treatments but coordinated policy at some governmental level. A complete package of financial incentives, bicycle facilities, and secure parking and showers at work make bicycling more attractive compared to car use (*16*). Vast networks of exclusive bicycle rights-of-way, secure bike parking, costly car ownership, and land use policies favoring compact, mixed-use neighborhoods all contribute to safe and frequent bicycling in European countries such as the Netherlands, Denmark, and Germany (*3*). There is a "safety in numbers" effect in that cities with higher bicycling rates have lower rates of injury and death for bicyclists (*2*). Pucher, Dill, and Handy conclude that a "complete system of bicycling infrastructure. . . may have far more impact than the sum of its individual parts" and that "a comprehensive approach produces a much greater impact on bicycling than individual measures that are not coordinated" (*2*, p. S122). Deliberate planning for bicycles using a holistic approach helps create the synergies that are necessary to get more people riding bikes.

Bike-transit integration

Comparatively fewer studies have investigated the bike-and-transit interface separate from bicycling in general, many of which are drawn from the European context. Similar to what has been found for overall levels of bicycle ridership, the studies that have been conducted on intermodality of bike and rail transit show mixed relationships among socioeconomic variables. One study finds higher rates of bicycling to transit among males, middle aged individuals, and either low or high income, while another study finds middle income and higher vehicle ownership rates to be associated with higher bike-on-rail rates (*21*).

Though vehicle ownership influences the choice of access mode, having a car available does not automatically translate to a preference for that mode. Research from three Munich train and metro stations and five UK train stations finds that between 48% and 55% of bike-and-ride passengers had a vehicle available on the day of the trip (*22*). Furthermore, bike-and-ride to faster public transportation systems—such as trains and express buses—is influenced by the overall rates of bicycling in the metro area (*22*). The correlation does not hold true for slower modes of public transportation. A study in the UK of integration between bike and light rail also finds that a coordinated accounting of secure bike parking, local topography, extent and quality of bike access routes, and traffic levels affected demand for bicycle parking at light rail stations (*23*).

One conflict for bike-transit integration, especially in locations where it is most successful, is that cyclists often indicate they wish to bring their bikes with them for use at both ends of the trip (*3*). Capacity constraints make this issue problematic during rush hours and peak use periods; agencies must balance the demand between non-cycling passengers and the inconvenience to bike riders who must leave their bikes parked.

Because European countries such as the Netherlands have some of the highest rates of bike and transit ridership in the world (*24*), it can be useful for transit agencies in North America looking for best practices to turn their attention eastward. While the Netherlands is now well-known for its cycling infrastructure, it was not until 1992 that the country developed a comprehensive policy that incorporated increasing bike-and-ride rates as an explicit policy goal (*24*).

Parking improvements were shown to improve user satisfaction of the transit experience from 5.3 to 7.1 on a 10-point scale and 11% of survey respondents thought the improvements were a reason to bicycle to the transit station more often (*24*). One important conclusion the author draws is that even in cities with safe bicycling routes, travelers did not bike to transit stations until parking was improved. This suggests that even in locations with low bicycling rates, good parking can have a substantial impact on increasing bicycling to transit stations.

Compared to bicycle access at the origin station, bicycle use at the destination station is substantially lower (*22*). This is because unless the rider brings his or her bicycle on the train or has a second bicycle stored at the egress location, it is not possible to continue the trip by bike. To help bridge this gap, short term bike rentals have been installed at many stations in the Netherlands. The bicycle rental system has replaced egress trips by other public transit providers—especially for non-recurring trips—and has led to increased train ridership (*24*).

Conclusion

The literature of influences on bike share, based on a combination of aggregate and disaggregate studies, is somewhat mixed and makes it difficult to draw definitive conclusions on how to best pursue increases in bike rates as a transit access mode. Nevertheless, some associations appear to be significant. Increases in the overall bike mode share may lead to increases in the bike-to-transit share. Urban form correlates that contribute to higher cycling mode shares include higher urban density, pedestrian- and bicycle-friendly neighborhood design, and shorter commuting distances. Infrastructure—particularly more bike lanes and secure bike parking at destination locations—also tends to influence bicycle commuting positively. It is less clear how significant socioeconomic factors are to bike ridership. In general, the same built environment and demographic associations hold true when studying influences on bike-to-transit ridership, though secure bike parking stands out as a necessary component of any plan to increase bicycle access. The clearest takeaway is that coordinated policy with a comprehensive set of bicycle improvement components is necessary to have a positive impact on bike access share. Case studies have shown that agencies and cities with explicit bike-transit policies have more success in increasing bicycling to transit stations.

Despite an emerging literature on bicycle–transit integration, there are few empirically based studies in the American context outside a handful of case studies (*21*). As such, the present research is rather exploratory in nature. It seeks to determine which characteristics are most associated with bicycling to transit.

METHODOLOGY

The Bay Area Rapid Transit (BART) District conducts periodic surveys of its ridership to account for mode of station access and rider characteristics. Consistent methodology between survey years enables analysts to directly compare responses from year to year. To more fully answer the question of what influences the bicycle share of transit access, this study relies primarily on a dataset compiled from those surveys. The analysis focuses specifically on the demographic characteristics of those who ride their bikes to BART in addition to built environment characteristics of the train stations.

Transit access survey

The transit access survey for this study was conducted by BART. The BART system is a heavy-rail transit system serving travelers in the San Francisco Bay Area in northern California. As of the time of the analysis the system had 43 stations over 104 linear track miles and widely varied built environments, located in the primarily urban counties of San Francisco and Alameda as well as more suburban counties of San Mateo and Contra Costa (*25*). The system is mature and has been in operation for about 40 years.

In 1998 and again in 2008, BART conducted a comprehensive survey of its ridership. The surveys asked questions regarding demographics, station access, and related transportation characteristics. Questionnaires were handed out on one day for each station in a random manner based on passenger volume to ticketed riders who appeared to be 13 years of age or older. The survey instrument was available in English, Spanish, and Chinese and a phone number was established for persons with disabilities to call in if they preferred. For the 1998 survey, BART received 40,887 usable surveys for an overall return rate of 42% (*26*). For the 2008 survey, BART received 52,625 completed surveys and 11 phone interviews; the figures represent a system-wide 46% return rate (*27*). The detailed survey methodology and statistical formulation is published in Appendix B of the final report (*27*).

Data analysis

People who access BART by bicycle are a subset of those who have chosen transit as their travel mode. As a result, the characteristics of the bike-to-transit individuals may be different from those who choose to use the bicycle as their primary origin-to-destination transportation mode. As described in the literature review, there is some overlap as well as disagreement in the academic consensus of which variables matter most when predicting the mode share of bicycles between the two population subgroups. To best analyze the interactions among the variables affecting the rate of bicycling to BART, this study calculates regression models at the station level on the 2008 home-based trip origins and 2008 non-home-based trip origins datasets separately. In both cases, the dependent variable is the log-transformed rate of bicycling. The independent variables are based on the literature and include: street network connectivity, bike parking, nearby bike infrastructure, median distance to the transit station, race, sex, vehicle availability, availability of vehicle parking (at work and at the station), number of household members, and income. Demographic data are drawn from the entire set of BART riders in one model and the subset of BART riders who arrived by bicycle in another. Each model uses the aggregate statistics from all station areas that had a non-zero bicycle access rate ($n = 42$ for home origins, $n = 41$ for non-home origins).

A measure of the connectivity of the transportation network is included as one of the independent variables in the analysis. Measures of street connectivity can give clues as to the likelihood that people will bicycle to destinations. Intuitively, the more easily accessible locations are by non-motorized means, the greater the chance is that a user will choose a non-motorized method of travel. Intersection density is defined as the number of intersections per unit area and is the measure used in this analysis (*28*).

The analysis used the 2008 TIGER/Line Shapefile set (*29*) to match the year of the survey, edited to include only the local roads—i.e. excluding limited-access freeways on which bicycle travel is restricted—in the four counties that BART serves. A 1.6-km (1 mi) buffer around each BART station was chosen as the study area for the calculations. One mile was used as the buffer distance because it nearly matches the median travel distance to stations from both home origins (1.12 mi) and non-home origins (0.97 mi) for all survey respondents (*27*). The GIS tools extracted intersections, local road length, and land area for analysis.

ANALYSIS

The analysis of the BART data covers descriptive statistics and a regression analysis of the most recent survey data. Each model specifies the natural logarithm of the bicycling rate as the dependent variable in a log-linear regression. The independent variables come from the survey data of the subset of BART riders who bicycled to the station and the characteristics of the stations as listed in the methodology section. To avoid over-specification of the models, a select number of socioeconomic variables were chosen based on correlation tests, though at least one from categories of race, income, household size, and vehicle availability were included. Built environment characteristics were included and an additional variable was included to account for the level of restrictiveness of bringing a bike on board during peak hours. This variable is intended to represent agency policy actions. The full set of variables tested is in Table 1. Three categories of models are run using independent variables in Table 1: data from home origins for bicyclists only, data from home origins for all BART riders, and data from home origins for bicyclists only.

Descriptive statistics

As a first step, univariate aggregate statistics of the bicycling rates to BART stations for both home and non-home origins are explored to establish a frame of reference for the bike access profile of the system. Of the 43 stations surveyed in 2008, four had been built since 1998 (Millbrae, San Bruno, San Francisco International Airport, and South San Francisco). At the aggregate system level, there was a modest increase in rates of bicycling to BART for all trip origins between 1998 and 2008, from 2.0% to 2.8%. The raw numbers of survey respondents who biked to the stations also increased, more than doubling from 865 to 1,762. The median increase in the rate of bicycling from 1998 to 2008 at the station level was 0.62%. For home origins only, the increase was from

TABLE 1 Model variable definitions

Variable	Definition
White	Percentage of respondents who are White
Female	Percentage of respondents who are female
3+ in Hhd.	Percentage of respondents with 3 or more household members (proxy for children)
No vehicle available	Percentage of respondents who have no vehicle available in household
Median dist to station	Median distance from origin to station (miles)
Bike lane	Sum of length of bike lanes within 1 mi radius of station (miles)
Bike Station	Presence of bike station (1=yes, 0=no)
Bike lockers	Number of bike lockers
Bike racks	Number of bike racks
Intersection density	Number of intersections per land area (sq. mi.) within 1 mi radius of station
Income \$0k–\$15k	Percentage of respondents with household income less than \$15,000
Income \$200k+	Percentage of respondents with household income greater than \$200,000
Bike restriction	Bike restricted in both directions for both peak periods (1=yes, 0=no)
Free parking	Percentage of respondents with free parking at work
Station parking	Presence of vehicle parking at the station (1=yes, 0=no)

2.5% ($n = 538$) to 3.5% ($n = 1,038$). In the non-home origin subset, the rate increased from 1.5% ($n = 305$) to 2.2% ($n = 713$). For the aggregate of home and non-home origins, the rate of change in bicycle access was greatest among all access modes (walk, car, transit). The bicycle share increased by 40%, while walking increased by 12%. The share of driving and riding other transit to BART both declined. Taking an aggregate view, the figures indicate there was generally an upward shift in rates of bicycling to BART from 1998 to 2008, notwithstanding the case of the SFO station, which had no riders. A one-tailed paired difference of means test confirms the rate increase on a station-by-station basis ($p < 0.001$). Other descriptive statistics for station aggregates are in Table 2.

Home origins regression model

Several models using the variables in Table 1 were run to determine the specification of the minimally adequate model. The final model, as shown in Table 3, fits the data well ($R^2 = .81$). The presence of a bike station is found to be a significant predictor of bicycling ($p < .001$), while the proportion of whites, the proportion of females, the number of bike lockers, and intersection density are significant at a level slightly greater than $\alpha = .05$.

An additional regression model, shown in Table 4, is calculated using demographic characteristics of survey respondents from all modes. This model also fits the data well ($R^2 = .85$), but only finds presence of a bike station, intersection density, and the bike restriction policy as significant predictors of bicycling to the station ($p \leq .05$). No socioeconomic variables are found to be significant in this model.

The results of the regression model confirm some of the findings from the academic literature. In the category of socioeconomic characteristics, a higher proportion of whites and females

TABLE 2 Variable descriptive statistics

Variable	Max	Min	Median	Std. Dev.
Bicycle rate – all origins (1998)	7.04%	0.03%	2.18%	1.52%
Bicycle rate – all origins (2008)	11.3%	0%	2.47%	2.56%
Change in rate (pct. pts.)	5.04%	−2.13%	0.62%	1.60%
White	96.5%	0%	70.0%	19.2%
Female	60.3%	0%	28.0%	14.3%
3+ in Hhd.	100%	16.6%	48.9%	19.2%
Vehicle available	100%	30.3%	59.0%	13.7%
Median dist to station (mi)	5.79	0.32	1.26	1.06
Bike lane (mi)	22.3	2.31	10.0	5.61
Bike Station (1=yes, 0=no)	1	0	0	0.26
Bike lockers	116	0	22	21.3
Bike racks	224	0	63	53.1
Intersection density (per sq. mi.)	338	46.6	200	92.9
Income $0–$15k	30.4%	0%	7.34%	6.67%
Income $200k+	23.3%	0%	5.53%	5.51%
Bike restriction (1=yes, 0=no)	1	0	0	0.35
Free parking	100%	12.2%	43.4%	19.1%
Station parking (1=yes, 0=no)	1	0	1	0.45

NOTE: All values for 2008 dataset unless otherwise specified. Demographics for home-origin bicyclists only.

TABLE 3 Linear Regression Model: Home Origins, Bicyclists Only (Minimal Model)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	−6.24	0.25	−24.49	0.000
White	1.31	0.35	3.80	0.001
Female	1.27	0.47	2.69	0.011
Bike Station	0.93	0.27	3.42	0.002
Bike lockers	0.01	0.00	2.83	0.008
Intersection density	0.01	0.00	4.53	0.000
Bike restriction	−0.60	0.25	−2.40	0.022

Residual standard error: 0.43 on 35 degrees of freedom
Multiple R-squared: 0.8083, Adjusted R-squared: 0.7754
F-statistic: 24.59 on 6 and 35 DF, p-value: < 0.001

TABLE 4 Linear Regression Model: Home Origins, All BART Riders

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	−3.47	1.95	−1.78	0.087
White	1.40	1.13	1.24	0.225
Female	−2.93	2.07	−1.42	0.167
3+ in Hhd.	−0.68	1.80	−0.38	0.707
No vehicle available	−0.46	1.60	−0.29	0.777
Median dist to station	−0.05	0.08	−0.60	0.551
Bike lane	−0.03	0.02	−1.55	0.133
Bike Station	0.71	0.31	2.25	0.033
Bike lockers	0.01	0.01	0.94	0.356
Bike racks	0.00	0.00	0.68	0.502
Intersection density	0.01	0.00	3.84	0.001
Income $0–$15k	1.31	5.04	0.26	0.797
Income $200k+	−0.49	1.93	−0.25	0.802
Bike restriction	−0.70	0.34	−2.06	0.049
Free parking	−0.38	0.61	−0.61	0.545
Station parking	−0.04	0.19	−0.20	0.845

Residual standard error: 0.4325 on 26 degrees of freedom
Multiple R-squared: 0.8559, Adjusted R-squared: 0.7727
F-statistic: 10.29 on 15 and 26 DF, p-value: < 0.001

who access BART by bike is associated with higher bike access at the station level overall, while the influence of income is insignificant. The two transportation economics variables—availability of a vehicle for the trip and free parking at work—are not significant, which indicates that with respect to BART riders, personal preferences may have larger influences than economic need on propensity to ride a bike. The urban form indicator, intersection density, shows a significant positive association with bicycling rates. For every additional intersection per square mile, the rate of bicycling increases by about 0.4%.

Bike parking is also shown to be significant. While the number of bike racks is not shown to have a significant influence on bicycling rates, secure bicycle parking is. Each additional bike locker is associated with a 1% increase in the bicycling rate, while rates at stations with bike stations are almost 100% greater than at those stations without when all other variables are held constant. From the data analyzed it is not possible to tell in which direction the causation is—and previous studies indicate that the relationship is likely circular—but it is accurate to conclude that more secure bicycle parking is an important component of maintaining higher rates of bicycling.

Stations with bike restrictions during both AM and PM peak periods are associated with lower rates of bicycling. This can be indicative of two phenomena. First, restrictions on bringing bikes on board may dissuade passengers from bicycling to the station. Bike restrictions are in place because the stations are the busiest in the system. Riders who cannot bring their bikes on board and cannot find a secure parking space are left with few options for bike storage. Relaxing restrictions may result in higher bike access rates at the expense of competition for space on crowded trains. On the other hand, the stations with the most restrictive bike access policies are also the stations that are most accessed on foot according to the station access data. Investigating substitution of walk trips by bike trips is outside the scope of analysis for the present study, so in this instance, it is not immediately clear what effect lifting the restrictions would have on increasing bike access.

No demographic variables are found to be significant in the regression model calculated from overall characteristics of BART riders from all access modes. This result indicates that personal preferences are more likely predictors of bicycling rates than socioeconomic makeup is when considering the general population. Only within the subset of bicycle riders do demographics begin to emerge as important associations in determining bicycling rates. However, the urban form measurement, intersection density, is still found to be significant, as are the bike station and bike restriction variables. The finding indicates the important role that infrastructure and policy play in promoting or deterring bicycling to the station.

Non-home origins regression model

Travel behavior is markedly different at non-home origins than at home origins. The percentage of people who walk to their non-home-origin station is 72%, compared to 31% who walk to the home-origin station (*27*). With respect to bicycling, one also would expect predictive factors to be different between the two origins. For example, one could hypothesize that secure bike parking is less important to those who bike to a non-home origin station, since, if they are traveling from work to home, it is likely they will leave their bikes at the station overnight. To test this theory, the same model is specified as was initially done for home origins.

The initially specified regression model for non-home origins has a poorer fit ($R^2 = .66$) than does the home-origin model (see Table 5). Furthermore, the only independent variable of significance is the bike restriction variable. The model helps confirm the supposition that travel behavior is significantly different based on origin location. Whether a station has a bike restriction

TABLE 5 Regression Model: Non-home Origins, Bicyclists Only

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	−4.60	1.07	−4.28	0.000
White	−0.02	0.74	−0.03	0.979
Female	−0.44	0.88	−0.50	0.618
3+ in Hhd.	0.54	0.83	0.65	0.524
No vehicle available	0.24	0.88	0.27	0.787
Median dist to station	−0.10	0.15	−0.64	0.527
Bike lane	−0.03	0.03	−1.13	0.267
Bike Station	0.30	0.44	0.68	0.504
Bike lockers	0.01	0.01	0.82	0.421
Bike racks	0.00	0.00	1.07	0.296
Intersection density	0.00	0.00	1.60	0.122
Income \$0–\$15k	0.52	1.23	0.42	0.678
Income \$200k+	1.08	1.80	0.60	0.555
Bike restriction	−1.02	0.45	−2.24	0.034
Free parking	0.91	0.77	1.19	0.245
Station parking	0.09	0.44	0.21	0.833

Residual standard error: 0.6114 on 25 degrees of freedom
Multiple R-squared: 0.6645, Adjusted R-squared: 0.4632
F-statistic: 3.301 on 15 and 25 DF, p-value: 0.004

makes sense as a predictor of bicycle access for non-home origins. Most people at non-home origins are presumably headed home where they would store their bikes, so not being able to bring a bike on board would prevent them from completing their journey. Regular commuters may have an incentive to store a bike at the destination location to circumvent the peak period restrictions, but it is clear that most do not take this approach.

IMPLICATIONS FOR POLICY

The BART Bicycle Access and Parking Plan (*30*) states that the agency's target for bicycle access in the AM peak period is an increase from the baseline of about 2% in 2002 to 2.5% in 2005 and 3.0% in 2010. While information broken down by time period was not available in the dataset used in this analysis, the trends revealed in the data indicate that BART is on its way to meeting its goals. Additional policy actions based on the relationships discovered may help further accelerate the increase of bicycle access, allowing BART to increase their bicycle access goals for future years.

Bike restrictions

Removing peak-period restrictions eliminates the burdens associated with cycling to the restricted stations. First, more people may choose to access the affected stations by bicycle. Since the majority of BART patrons access the six most bike-restricted stations by foot, shifting the mode to bicycles translates to the stations achieving a larger catchment area than currently. The added service area makes BART more accessible to people living in neighborhoods that are close but not immediately served by the system. Second, removing the ban of on-board bikes enables cyclists to complete trips that are not otherwise possible. For example, there is no direct bicycle access across the San Francisco Bay from San Francisco to Oakland. Removing the restriction enables transit to fill the critical gap in the travel network.

Although modifying the rush-hour bicycle policy may ameliorate issues for bicyclists, it may exacerbate problems for other travelers by introducing new pressures on limited space in crowded trains. Various agencies handle on-board bike storage during peak periods differently through dedicated bike cars or bike hooks, for example. However, BART may not be able to handle the additional space required by bicycles without substantial investment in dedicated cars or innovative storage. The Transbay link—the route that lacks a bicycle connection—carries nearly half of the agency's passengers on an average weekday (*31*), making capacity a premium on the route.

One workaround that does not require on-board space, however, may be a well-designed bicycle rental system at popular destination stations. Patrons could ride their own bikes to the origin station and use a low-cost rental bicycle at the end of the transit trip. Additionally, riders who access BART by other modes would have the option of using a bicycle to egress the station. Thus, an ancillary benefit to the bike-rental system is that it could increase the level of bike ridership of people who may not ordinarily consider traveling by bicycle. Another alternative to loosening bike restrictions is implementing a grant or subsidy program to help riders purchase folding bikes such as is being studied at Metro in Los Angeles County (*32*).

Parking

One of the important factors that emerges from the different analyses conducted is the amount of bicycle parking at the station. By varying measures, bike racks, bike lockers, and bike stations are all found to be significant predictors of either higher rates of bicycling or greater changes in levels of bicycling to BART stations. These results echo findings from other academic sources and case studies. Especially when traveling from home origins, secure bike parking appears to matter most to riders.

An oversupply of parking can spur bike access by providing guaranteed and easy-to-find parking (*24*). Policy goals should thus focus first on meeting demand at all stations, followed by oversupplying secure parking at key stations. Priority should be given to bike lockers over racks, though bike racks are appropriate where potential for shorter trips is high. Without more intimate knowledge of the user characteristics and utilization rates of bicycle parking at BART, however, it is difficult to make specific recommendations for what type of parking belongs where.

Conversely, availability of vehicle parking—whether at work or at the BART station—was not found to be significantly associated with bicycling to stations. The finding can be explored further by measuring impact of vehicle parking more granularly: number of parking spaces per lot, estimated time to fill, and parking costs may all have varying influences on the decision to bicycle.

Safety

The survey data studied indicate that more female bicycle riders at a particular station predicts higher rates of cycling for that station. More women riding may indicate a higher real or perceived level of safety in the area (*18*). The relationships related to female riders found in the survey data may point to specific locations worth examining closely for what station and local area improvements have been successful in increasing safety, which can then be extended to other locations in the system. Because broader data from the general study area were not incorporated in any of the models, it was not possible to conclusively determine effects of crime or individual perceptions of safety on bike ridership.

Another variable that falls in the realm of safety is on-street bicycle infrastructure. Bike routes were not studied as part of this analysis because there is little distinction between a signed route and other low-to-medium volume mixed-traffic streets. Bike lanes were analyzed, and while the length of bike lanes was not found to be a significant predictor of increased cycling to transit, greater intersection density—and therefore greater connectivity—was found to be. Connectivity specifically for bicyclists can be improved by adding dedicated infrastructure, such as bike paths and separated bike lanes or cycle tracks, along existing routes or by creating new routes. A safety element exists here by separating cyclists from faster moving motor vehicle traffic, especially helpful for less experienced and new cyclists. Although BART does not have planning authority for improvements outside the station area, it can work with local cities and the Metropolitan Transportation Commission to ensure that new bike facilities connect with transit.

CONCLUSION

The approach to this study was to perform a cross-sectional analysis of a dataset collected from travel behavior surveys to better understand the predictors of bicycling to transit. The data for this analysis were drawn from BART riders who arrived to the station by bicycle, rather than from the general population. Bicycle-specific variables related to the built environment, infrastructure, and policy are found to have the greatest influence on bicycling to transit. Readers are cautioned that, as in all case studies, the results are specific to the particular context in which it was conducted—in this case, to a mature, fixed-rail heavy transit system. Further empirical research is needed to draw general conclusions about the influences on bicycling to all forms of transit.

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