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IMPACTS OF BUS STOP IMPROVEMENTS

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16. Abstract

Improving bus stops by providing shelters, seating, signage, and sidewalks is relatively inexpensive and popular among riders and local officials. Making such improvements, however, is not often a priority for U.S. transit providers because of competing demands for capital funds and a perception that amenities are not tied to measurable increases in system effectiveness or efficiency. This study analyzes recent bus stop improvements made by the Utah Transit Authority (UTA) to determine whether, and to what extent, the improvements are associated with changes in stop-level ridership and demand for Americans with Disabilities Act (ADA) paratransit service in the areas immediately surrounding improved bus stops. The study compares ridership and paratransit demand from before and after the improvements at the treated stops and at a set of unimproved stops selected using propensity score matching to control for demographic, land use, and regional accessibility influences. The analysis shows that the improved bus stops are associated with a statistically significant increase in overall ridership and a decrease in paratransit demand, compared to the control group stops. These outcomes are important for transit service providers as they seek to increase overall ridership and reduce costs associated with providing paratransit service.

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LIST OF ACRONYMS

ADA	Americans with Disabilities Act
PSM	Propensity score matching
UDOT	Utah Department of Transportation
UTA	Utah Transit Authority

EXECUTIVE SUMMARY

Improving bus stops by providing shelters, seating, signage, and sidewalks is relatively inexpensive and popular among riders and local officials. Making such improvements, however, is not often a priority for U.S. transit providers because of competing demands for capital funds and a perception that amenities are not tied to measurable increases in system effectiveness or efficiency. The literature on the effects of bus improvements is not extensive and is primarily comprised of analyses that make use of descriptive statistics, with little or no control of possible confounding variables.

This study analyzes recent bus stop improvements made by the Utah Transit Authority (UTA) to determine whether, and to what extent, the improvements are associated with changes in stop-level ridership and demand for Americans with Disabilities Act (ADA) paratransit service in the areas immediately surrounding improved bus stops. The study compares ridership and paratransit demand from before and after the improvements at the treated stops and at a set of unimproved stops selected using propensity score matching to control for demographic, land use, and regional accessibility influences.

The analysis shows that the improved bus stops are associated with a statistically significant increase in overall ridership and a decrease in paratransit demand, compared to the control group stops. Specifically, between 2013 and 2016, improved bus stops saw ridership increases that were 92% *higher* than increases at the control group stops, while also experiencing ADA paratransit demand increases that were 94% *lower* than at the control stops.

These outcomes are important for transit service providers as they seek to increase overall ridership and reduce costs associated with providing paratransit service.

1.0 INTRODUCTION

1.1 Problem Statement

U.S. public transportation providers have limited capital investment budgets and large service areas, which means that decisionmakers are under significant pressure to demonstrate meaningful returns on the investments they choose to make. Improving existing bus stops by adding amenities such as shelters, benches, sidewalks, etc. is relatively inexpensive and is popular with local officials and transit riders, but do such improvements lead to measurable improvements in system effectiveness or efficiency? Our research sought to measure quantifiable returns on bus stop amenity investments by looking at ridership levels and paratransit service demand. Originally, our research scope was limited to improvements made to a single corridor—the route of the #41 bus line along 3900/4100 South in Salt Lake County, Utah—by the Utah Transit Authority. The improvements included creating ADA-compliant concrete pads and installing a variety of fixtures, including trash cans, benches, shelters, better connections to sidewalks, and (at a grocery store) a shopping cart corral. We also planned to analyze a series of qualitative and quantitative data along this corridor to determine whether, and the degree to which, the investments can be associated with changes in both traditional effectiveness measures (e.g., ridership and customer satisfaction), as well as less traditional measures (e.g., possible reductions in paratransit demand, vehicle maintenance costs, customer complaints, and liability claims). In the end, we opted to increase our geographic scope to include all bus stops in Salt Lake County in our analysis—thereby increasing the statistical rigor of our analysis—and limit our output variables to ridership and ADA paratransit demand.

1.2 Objectives

The goal of this research is to help identify potential impacts arising from bus stop infrastructure implemented by public transportation providers. Amenities like shelters, seating, universally accessible bus stop platforms, trash receptacles, bike parking, signage and lighting are all popular with riders and local government partners, but do they lead to measurable improvements? Providing evidence on performance metrics associated with stop improvements would help inform investment decisions associated with “first-mile/last-mile” improvements, which have been the subject of substantial interest in the Salt Lake region and are currently prioritized in Utah Transit Authority’s annual performance goals.

1.3 Scope

During 2014-16, UTA upgraded stops along several selected bus routes in the Salt Lake County portion of the agency’s five-county service area. With some minor variations, the improvements involved upgrading stops from simple sign poles in roadside planting strips to the construction of ADA-compliant concrete pads connected to surrounding sidewalk networks and the installation of shelters, benches, and trashcans (Figure 1.1). Our objective for this research is to determine whether, and the degree to which, the improvements can be associated with changes in ridership and ADA paratransit demand. To do this, we analyzed data from periods before and after the improvements and made comparisons between the improved bus stops and a set of unimproved stops carefully chosen with propensity score matching to control for demographic, land use, and regional accessibility variables that might affect ridership and paratransit use.

Figure 1.3.1 Before and After Bus Stop Amenity Improvements Along the #41 Bus Line in Salt Lake County with Google Street View.

1.4 Outline of Report

To provide further introductory context, we continue next with a literature review section. We then provide a chapter on research methods, outlining in detail our primary analytical tool—propensity score matching. We follow this with a chapter on data collection and classification and then proceed to a chapter presenting and analyzing our results. We end the report with a chapter offering conclusions, limitations, and recommendations for further analysis.

1.5 Literature Review

While the professional literature on the qualitative aspects of bus stop amenities is fairly robust, there are few studies that focus on the quantitative impacts of such amenities. This is somewhat anomalous given how focused most transit agencies are on calculating the fiscal and ridership impacts of other types of capital investments (Cham et al., 2006; Hagelin, 2005). A number of studies examine stop-level bus ridership as a function of transit service characteristics and the environment surrounding the stops (Chakour and Eluru, 2016; Dill et al., 2013; Estupiñán and Rodríguez, 2008; Ryan and Frank, 2009; Wu and Murray, 2005). The few studies focusing on the features of the stops themselves are presented here.

Brown et al. (2006) conducted a cross-sectional analysis of the relationship between transit ridership and built environment characteristics in the areas surrounding bus stops, and at the stops themselves, in the Triangle region of North Carolina. Scoring amenities such as signs, shelters, schedules, lighting, and paved landings, the authors created a Bus Stop Index and showed the index had a significant and positive effect on bus ridership, with a unit increase in the index resulting in a 31% increase in ridership. In addition, the authors found that destination types, pedestrian facilities, and architectural design correlated with increased ridership. The study, however, used rider survey data to estimate ridership and did not control for system-wide trends in ridership. Talbott (2011) also found correlations between ridership and amenities, although the study's lack of controls for possible confounding variables limited its ability to speak to causation questions.

Most of the qualitative bus stop literature supports the deployment of full-amenitied stops, with a particular emphasis on the provision of bus shelters (Broome et al., 2010; Project for Public Spaces, Inc. and Multisystems, Inc., 1999; Zhang, 2013). In at least one study, the cleanliness and characteristics of the environment where the stop is located was associated with improved perception of bus transit and increased ridership (Woldeamanuel and Somers, 2016). Chu (2004), however, argues that stop amenities might have a greater effect on stop selection among existing riders than in attracting new riders. While extreme weather such as extreme temperatures, heavy rainfall, snow, and wind negatively affect ridership (Guo et al., 2007; Stover and McCormack, 2012), a recent study shows that bus shelters play a role in mitigating some of these ridership losses (Miao et al., 2016).

A fairly common method used by transit agencies to understand travel behaviors is to evaluate the degree to which transit riders are satisfied with the service they receive (Schiefelbusch, 2015; Van Acker et al., 2010). Customer satisfaction and preference are generally measured through rider surveys and the benefits are difficult to quantify (Cham et al., 2006; Iseki and Taylor, 2010; Krizek and El-Geneidy, 2007; Project for Public Spaces, Inc. and Multisystems, Inc., 1999; Talbott, 2011). Stated-preference studies, in the forms of surveys, interviews, focus groups, visual preference surveys, and crowdsourcing, show stop amenities are important to current and potential riders (Chu, 2004; Ewing and Bartholomew, 2013; Higashide and Accuardi, 2016; Krizek and El-Geneidy, 2007; Project for Public Spaces, Inc. and Multisystems, Inc., 1999), though some studies reveal that user satisfaction is more related to reliable and frequent services than physical amenities (Higashide and Accuardi, 2016; Iseki and Taylor, 2010). Looking at the requirements of “encumbered” riders and riders with disabilities, Verbich and Ahmed (2016) highlight the importance of bus shelters for riders who travel with children or shopping bags. While it is well-established that wait time can have a substantial influence on users’ experience of transit (Litman, 2008), there is some evidence that basic amenities like benches and shelters can significantly reduce users’ perception of wait times (Fan et al., 2016; Yoh et al., 2011).

Facilitating links between activities is one of the principal functions of transit systems (Taylor et al., 2009). That type of accessibility is especially important for those with impaired mobility. Although the term “paratransit” includes many types of non-auto services, here we limit ourselves to those non-fixed route services operated by public transit agencies for people with disabilities in compliance with the ADA (Lave and Mathias, 2000). The cost of providing paratransit is generally much higher than fixed-route service, frequently requiring large subsidies from transit agencies and local governments (Balog, 1997; Lave and Mathias, 2000; Wu et al., 2011). Despite the fact that bus stops are important features for making a transit system accessible to and usable by people with disabilities (Balog, 1997) and public transit agencies' awareness of the importance (Thatcher et al., 2013), we found few studies examining the relationship between bus stop amenities and ADA paratransit demand. Some studies focus on optimization of bus stops with ADA improvements (Wu et al., 2011) but do not assess the cost-effectiveness of those improvements. An Australian study (Broome et al., 2010) found that the availability of bus shelters is one of the reported features facilitating bus use for older adults. An analysis of 17 improved bus stops in the Portland, Oregon region showed a 96% increase in the deployment of lifts/ramps by fixed-route buses at the stops, and a 12% decrease in ADA paratransit demand in the areas surrounding the stops, after the improvements (Thatcher et al., 2013). A similar before-after comparison in Olympia, Washington found a 37% increase in lift/ramp deployments at improved stops, compared to a 16% increase system-wide (Thatcher et al., 2013). These studies, however, did not include controls for other possible influential variables.

Throughout our evaluation of the literature, we found a need to develop more rigorous quasi-experimental design to compare data from before and after the introduction of bus stop improvements.

2.0 RESEARCH METHODS

2.1 Overview

The focus of this study is to measure the stop-level impact of bus stop improvements on bus ridership and demand for ADA paratransit service. Our analysis is based on before and after improvement observations for both the stops with improvements (the treatment group) and comparable stops without improvements (a control group). Thus, a critical part of the study is finding reliable counterfactual bus stops to serve as the control group (Cao and Schoner, 2014; Ewing and Hamidi, 2014).

Although randomized experimental design is the most rigorous method to make a causal inference, it is infeasible in many real-world situations—such as the planning interventions in this study—because the assignment of treatment does not happen randomly (Rosenbaum, 2010; Shadish et al., 2002). As a quasi-experimental study, this study uses propensity score matching (PSM) to reduce selection bias that may result in misleading comparisons (Rosenbaum and Rubin, 1983).

2.2 Propensity Score Matching

Propensity score matching (PSM) constructs a comparison group that is statistically similar to the treatment group in terms of the observed characteristics in pre-treatment conditions—both for anticipated confounding variables as well as factors predicting treatment selection. Each treatment group stop is matched with a stop that remains unimproved (in both before and after periods) based on propensity score, which is a scalar function of the observed covariates. Then, the average difference in outcome variables between before and after treatment periods is compared between treatment and comparison groups to find the possible effects of making the stop improvements (Leite, 2017). In this way, it is possible to control for selection bias (Dehejia and Wahba, 2002) and the treatment assignment resembles a randomized experiment (D'Agostino, 1998).

To accomplish this, we used the "MatchIt" package in R 3.4.0. For our first step, we performed a series of t-tests to check the differences between treatment and comparison groups of stops before matching. Then, with a binary logistic regression model, we estimated propensity score as the probability of receiving bus stop improvement conditioned on observed covariates. Because this is a prediction model, there was no need to be concerned about the multicollinearity of the covariates or the statistical significance of the model (Cao et al., 2010). Next, we tried to find bus stops without improvements that are similar to treatment group stops based on propensity scores. To do this, we used a nearest neighbor within-caliper matching method, which found the untreated stops with the closest propensity scores to the propensity score of each treated stop. Using a caliper of 0.25, we searched for matches only among untreated bus stops whose propensity scores were within 0.25 standard deviation of the propensity scores of treated stops. This allowed us to control for pre-matching selection bias (Leite, 2017; Rosenbaum and Rubin, 1985). We evaluated the performance of the matching outcomes using t-tests to determine the degree to which the matched treatment and control groups were balanced. Once the control and treatment groups were appropriately matched, we calculated the impact of bus stop improvements on bus ridership and paratransit demand by measuring average treatment effect (ATE), which is the difference in the mean rate of change for each group over the before and after time periods (Cao et al., 2010).

3.0 DATA & VARIABLES

3.1 Overview

The bus stops we initially included in the treatment group were the 30 stops located in Salt Lake County that UTA improved between December 2014 and February 2016. The stops we analyzed for possible inclusion in the control group were the remaining 2,221 stops in Salt Lake County that as of February 2017 remained unimproved.

3.2 Control Variables for Propensity Score Matching

For the propensity score matching process, we selected variables shown in the literature to have an association with stop-level transit ridership (Dill et al., 2013; Ewing et al., 2015). These variables, listed in Table 3.2.1, fall into three categories or orientations: demographic, land use, and accessibility. The 10 demographic variables we selected represent a traditional array factors commonly used in analyses of transportation behavior. Our land use variables follow the now customary five-D formulation of Density, Diversity, Design, Destination accessibility, and Distance to transit. Two measures of diversity were used: the first measures the balance between jobs and population; and the second is an index of land use mix. Job-population balance ranges from 0, which means an area has only jobs or residents, to 1, indicating that there is 1 job per 5 residents. Entropy index is a mixed use variable indicating 0 for a single land use and 1 for evenly mixed land uses (Ewing and Hamidi, 2014; Ewing et al., 2015). Two of our land use variables—Transit Stop Density and % Regional Destination in 30 min by Transit—do double duty by also incorporating a measure of transit service, which the literature shows to be an important influence (Dill et al., 2013).

The geographic unit of analysis for most of our variables is a half-mile buffer around each stop. In many cases, these buffers intersect with several census block groups, which required us to assign proportionally the American Community Survey (ACS) data to each stop buffer. We used the same apportioning method with the parcel-level tax assessor's land use data and Traffic Analysis Zone (TAZ) level regional destination data.

Table 3.2.1 Variable Description

Variables	Description	Sources
Outcome Variables		
% Change in Bus Ridership	Percent change of annual bus ridership at a stop between 2013 and 2016	UTA
% Change in Paratransit Demand	Percent change of annual paratransit demand within a 1/4 mile network buffer around a stop between 2013 and 2016	UTA
Control Variables for Propensity Score Matching		
Total Household	Total household within a ½ mile buffer around a stop	ACS 2011-2015
Household Size	Average household size within a ½ mile buffer around a stop	ACS 2011-2015
% Non-Hispanic White Population	Percentage of non-Hispanic white population within a ½ mile buffer around a stop	ACS 2011-2015
% Population 65 years and over	Percentage of population 65 years and over within a ½ mile buffer around a stop	ACS 2011-2015
% Household Living Alone	Percentage of household living alone within a ½ mile buffer around a stop	ACS 2011-2015
% Students in College	Percentage of students in college and grad school within a ½ mile buffer around a stop	ACS 2011-2015
Median Household Income	Median household income in the past 12 months within a ½ mile buffer around a stop	ACS 2011-2015
% Population with Annual Household Income below Poverty Level	Percentage of population with annual household income below poverty level within a ½ mile buffer around a stop	ACS 2011-2015
% Renter Occupied Household	Percentage of renter occupied household within a ½ mile buffer around a stop	ACS 2011-2015
% Household without Vehicle Available	Percentage of household with no vehicle available within a ½ mile buffer around a stop	ACS 2011-2015
Activity Density	Activity density within a ½ mile buffer around a stop *population + employment / gross land area in a square mile*	ACS 2011-2015; 2013 LEHD
Job Population Balance	Job population balance within a ½ mile buffer around a stop *1 - [ABS(employment - 0.2*population)/(employment + 0.2*population)]*	ACS 2011-2015; 2013 LEHD
Entropy	Land use mix within a half mile buffer around a stop *Entropy= -[residential share* ln(residential share)* *+ commercial share*ln(commercial share)* *+ public share*ln(public share)]/ln(3)*	WFRC; Tax Assessors data
% of 4 Way Intersection	Percentage of four-way intersections within a ½ mile buffer around a stop	TomTom
Transit Stop Density	Number of transit stops within a ½ mile buffer around a stop	AGRC
% Regional Destination in 20 min by Car	Percentage of regional employment within 20 min by car in a TAZ where a stop located in.	2010 Census; 2013 LEHD
% Regional Destination in 30 min by Transit	Percentage of regional employment within 30 min by transit in a TAZ where a stop located in.	2010 Census; 2013 LEHD

3.3 Outcome Variables

The two outcome variables in this study are the rates of change in bus ridership and paratransit demand between the periods before and after the stop improvements. To neutralize seasonal variations in the data, the "before" and "after" data capture annual ridership/paratransit demand—measured from March 1 to February 28 for both 2013-14 and 2016-17. For convenience, we refer to the "before" period as 2013 and the "after" period as 2016.

Ridership data are from Automated Passenger Counter on-board sensors that measure the number of boardings for each stop by bus route. We aggregated this data at each stop to reflect the total number of boardings for all routes using the same stop. To measure ADA paratransit demand, we used paratransit deployment data with geocodable pick-up location information. The geographic capture area we used for this data included all deployments within a quarter-mile network buffer around each bus stop. For both variables, we used percentage rates of change in ridership instead of absolute ridership due to large ridership variations from stop to stop.

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4.0 RESULTS & ANALYSIS

4.1 Propensity Score Matching

Before matching, the 30 stops improved in 2014-16 were significantly different with the other 2,221 unimproved stops for all covariates (Table 4.1.1). During the matching process, we had to drop six of the stops in the initial treatment group because of difficulties in finding comparable matches in the non-treatment group. However, we succeeded in finding comparable matches for the remaining 24 treated stops, creating a total of 24 improved-unimproved pairs of stops that were not statistically different from each other for any of the control variables. Figure 4.1.1 shows the location of all 48 stops.

Table 4.1.1 Mean Differences of Observed Covariates for Stops that were Improved in 2014-16 and Unimproved Stops during the Pre-Improvement Time Period

Variables	Before Matching (Mean)			After Matching (Mean)		
	Stops Improved 2014-16	Un-Improved Stops	Mean Diff.	Stops Improved 2014-16	Un-Improved Stops	Mean Diff.
Total Household	2,083	1,705	378*	2,021	2,129	-108
Household Size	2.36	2.82	-0.47***	2.53	2.49	0.04
% Non-Hispanic White Population	60.95	68.94	-7.99**	58.48	59.88	-1.40
% Population 65 years and over	9.19	10.88	-1.69**	8.52	8.25	0.27
% Household Living Alone	43.55	29.55	14.00***	38.33	40.79	-2.45
% Students in College	13.45	10.65	2.81*	12.28	13.01	-0.73
Median Household Income	39,910	55,185	-15,275***	41,029	40,777	252
% Population with Annual HH Income below Poverty Level	24.46	16.80	7.66***	23.95	22.34	1.61
% Renter Occupied Household	69.13	44.33	24.80***	65.42	66.10	-0.67
% Household without Vehicle Available	16.44	8.32	8.11***	13.29	13.79	-0.51
Activity Density	15,082	8,357	6,724***	13,303	12,610	693
Job Population Balance	0.29	0.55	-0.26***	0.32	0.38	-0.07
Entropy	0.83	0.69	0.14***	0.83	0.77	0.06
% of 4 Way Intersection	0.39	0.27	0.12***	0.37	0.35	0.02
Transit Stop Density	38.63	25.32	13.31***	33.58	36.42	-2.83
% Regional Destination in 20 min by Car	56.31	54.62	1.69**	56.75	55.96	0.78
% Regional Destination in 30 min by Transit	24.66	19.83	4.83***	24.01	23.70	0.32
Number of Bus Stops	30	2,221		24	24	

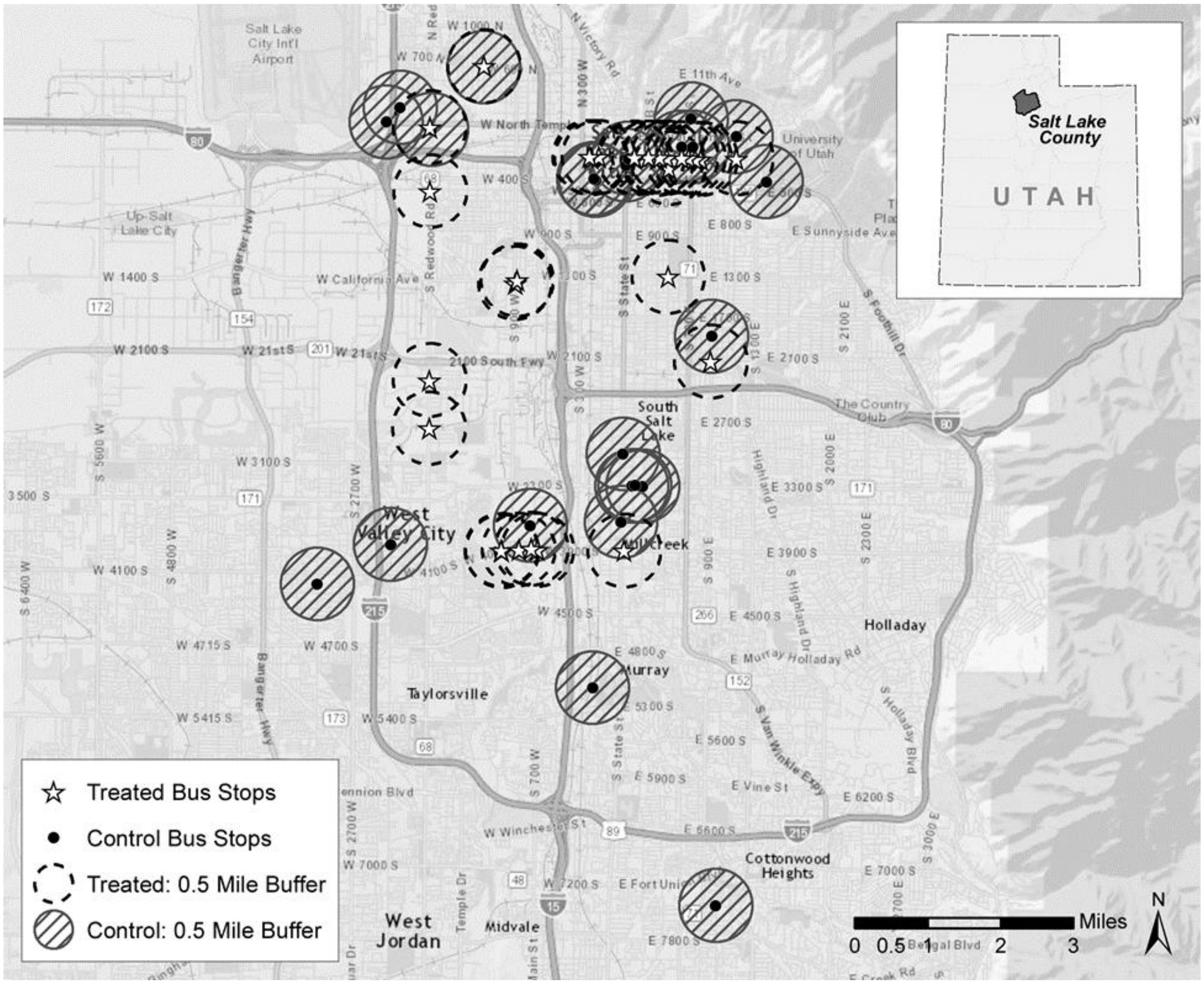

Figure 4.1.1 Locations of the Bus Stops Matched Using Propensity Scores.

4.2 Average Treatment Effect

With the successful matching of stops, we were able to estimate the effect of bus stop improvement on the rates of change in bus ridership and ADA paratransit demand for the two groups. To do this, we calculated the difference in mean percentage change between treatment group and control group over the before and after time periods, generating an average treatment effect (ATE) for both ridership and paratransit demand (Table 4.2.1).

The results show that the mean percentage increase in bus ridership between 2013 and 2016 was 2.39% for the control group stops. The mean increase for the treatment group stops, however, was almost double, 4.57%. In other words, stops with improvements experienced an

ATE 2.19 percentage points higher than unimproved stops, a difference that is statistically significant at the 0.05 level. This means that the growth rate of bus ridership is 92% higher at bus stops with improvements than at stops without improvements.

ADA paratransit demand in the buffer areas surrounding the control group bus stops saw an increase of 2.37% between 2013 and 2016. Demand in the areas around the treatment group stops, however, increased only 0.13%. This ATE of -2.24 percentage points is also significant, with a p-value of 0.041. Put another way, the growth in paratransit demand was 94% lower in the areas around the stops with improvements than around those without.

Table 4.2.1 The Effect of Bus Shelter Improvement on the Rates of Changes in Bus Ridership and Paratransit Demand around the Bus Stops

Outcomes	**(A)**	**(B)**	**(C)** = (A) – (B)	**(D)** = (C) / (B)
	Mean of Treatment Group	Mean of Control Group	Average Treatment Effect (ATE)	ATE/ Control Ratio
% Change in Bus Ridership between 2013 and 2016	4.57	2.39	2.19**	0.92
% Change in Paratransit Demand between 2013 and 2016	0.13	2.37	-2.24**	-0.94

5.0 CONCLUSIONS, LIMITATIONS & RECOMMENDATIONS

The aim of this study was to determine whether improvements in bus stop amenities could be associated with observed changes in bus ridership and demand for ADA paratransit services. Using propensity score matching to control for possible confounding variables, we determined such associations could be established for the data within our study. As outlined in the previous section, those associations are both substantial and statistically significant, with ridership at improved stops increasing at a rate 92% greater than at unimproved stops and ADA paratransit demand in the areas near improved stops increasing at a rate 94% lower than in areas surrounding unimproved stops.

Although it would be tempting to view the ridership increase as supporting a conclusion that improving bus stop amenities leads to increases in overall bus ridership, we cannot make that claim. It may be that all of the difference in ridership we observed was comprised of pre-existing riders who simply switched from using unimproved stops to stops with improvements, as Chu (2004) argues. The geographic proximity of some of the stops in the two groups, as depicted in Figure 4.1.1, suggests such an explanation is plausible. Whether all of the increase came from these "switchers," or from new riders, or from pre-existing riders who now ride more often, or from a combination of these possibilities, we leave for another day. However, even if we assume that all of the increase came from "switchers," we can at least assert that the improvements appear to be popular, which confirms our opening anecdotal statements about bus stop amenities enjoying political and popular support.

Perhaps the more important finding from this study is the reduced ADA paratransit demand we observed in the areas surrounding the improved stops. Although the pre-existing conditions at the treatment group stops varied to some extent, many, like those depicted in Figure 1.3.1, lacked a stable, level pad from which a wheelchair could easily board a bus. Many also lacked sidewalk connections that would facilitate wheelchair access to the stop location. In short, many of these stops effectively inhibited those with mobility-based disabilities from getting to UTA's scheduled bus service. The lower increase in ADA paratransit demand we observed at the improved stops supports the possibility that the improvements, especially the sidewalk connections and concrete pads, facilitated a shift from paratransit service to regular bus service for riders with mobility limitations. To the extent that that is true, it would mean substantial increases in mobility and accessibility for those riders, and important financial savings for UTA from reduced demand for costly paratransit services. More analysis is required to reveal the validity of these possible explanations.

Our study has a number of additional limitations. First, the study is based on a small number of samples in a specific geographic area, Salt Lake County, Utah. Further research with more sizable samples in multiple geographic regions would likely produce more generalizable results with greater statistical power. Second, many of the stops in our treatment group were located in concentrated corridors along two specific bus routes (Figure 4.1.1). It is possible that the corridor-based treatments potentially strengthened the effect size of bus stop improvements by having improvements at both the origin and destination stops for many riders. There also may be a cumulative indirect effect on ridership from corridor-wide improvements coming from the positive associations noted earlier between stop improvements and customer satisfaction (Project for Public Spaces, Inc. and Multisystems, Inc., 1999). Third, our study looked at ridership changes in time periods immediately following the introduction of the improvements. It could be that the effect of the improvements is larger (or smaller) the longer the period of time between improvement and observation. Lastly, the variables we used in the propensity score matching for controlling possible confounding influences were drawn from studies of ridership on regular bus services. It may be that these variables operate differently with ADA paratransit patrons, and there could be variables unique to those populations that we missed entirely.

Notwithstanding these limitations, our study has demonstrated important advances in the study of the micro-scale environment of the bus stop. Methodologically, the study represents one of the few examples of the use of propensity score matching in a planning context (Ewing, 2015). To our knowledge, the technique's use in this study is the first instance of its application to assess impacts of small-scale urban design features. It may prove to be useful in other contexts as part of a suite of techniques to analyze the role urban design plays in our communities (Ewing and Bartholomew, 2013).

More fundamentally, this study augments our understanding of how improvements in bus stops can affect human interactions with transit services. It is frequently asserted in transit design literature that the bus stop is the point of first contact between a transit agency and its customer (European Union, 2013). How a stop is designed and constructed sends important signals to the public about the transit agency's attitude toward existing and potential riders—are they to be valued, facilitated, and coaxed into riding, or merely accommodated. This study is the first to assess quantitatively the impact of this relationship at the bus stop, using a before-after improvement research design with measures to control for possible confounding variables. Crucially, this study highlights the potential impacts of stop improvements on populations with mobility related disabilities. Much more work needs to be done to understand these connections.

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