TRANSIT-SUPPORTIVE MUNICIPAL POLICIES AND STATION-LEVEL RIDERSHIP

A Direct Ridership Modelling Analysis

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ABSTRACT
Transitways represent large public investments whose positive impacts must be maximized whenever possible to justify the expenditures they entail. Prominent among those looked-for positive impacts is the encouragement of automobile-to-transit mode shifts by attracting increased transitway ridership. Transitways have a ridership impact on their own, but their stations exist in an environment of municipal policies which may not aim to maximize transitway use, and often aim to maximize automotive mobility. This paper explore the impact of municipal policies on transitway ridership through a national study of 16 metropolitan areas to answer the research question: What role and transit-supportive public policies implemented around transitway stations in boosting transitway ridership? The authors employ a Direct Ridership Model (DRM) to predict boarding at the station level. Station-area focused policies promoting affordable housing and explicit policies calling for sidewalks on all streets in station areas or entire cities have a significant and positive impact on ridership if there are sufficient potential destinations in the immediate station area. The results stress the importance of station area affordable housing as a transit system efficiency measure, as well as for the social equity reasons it is usually encouraged. The authors recommend the strengthening of pro-affordable housing policies and pro-sidewalk policies in station areas, support and encouragement for the neighborhood-scale commercial development that is required for their efficacy and the continued implementation of pro-affordable housing policies and pro-sidewalk policies.

INTRODUCTION

Despite their recent growth, transitways operate in an overall public policy environment that still strongly favors the automobile *(1, 2)*. This policy environment makes encouraging mode shifts from automobile to transit unnecessarily difficult. Policies ranging from zoning ordinances to off-street parking requirements often date from an era when the unimpeded movement of automobiles was the primary goal of transportation planning. That goal has changed—supplanted by a variety of goals ranging from regional accessibility to vehicle-miles traveled (VMT) reduction to increased transit use. The major investments represented by transitways may call for a reevaluation of existing public policies in station areas in the interest of promoting mode shifts from automobiles to transitways.

This report focuses specifically on policies local governments may implement in station areas intended as "force multipliers", so to speak—enhancements to the basic ridership attraction effects of transitways themselves. To compare systems in broadly comparable metropolitan areas, the research focuses on a set of peer regions defined by the Twin Cities Metropolitan Council (Hiniker, 2013, unpublished material). The authors obtained boarding data for each of these systems shown at the station level, and estimate a direct ridership model to explain ridership as a function of surrounding transit-supportive policies, controlling for transit mode and service characteristics, as well as station area built environment and social characteristics.

LITERATURE REVIEW

Traditionally, transitway ridership forecasting efforts have depended on the classical, four-step travel demand modeling process, in widespread use since the 1950's. Four-step models effectively treat trip generation, trip distribution, mode split and route assignment as separate processes. This approach considers the impacts of earlier steps on later steps, but fails to account for feedback loops from later steps to earlier steps—for example, how congestion (considered in the route assignment step) can impact future development decisions (considered largely in the trip generation step) *(3)*. The Transportation Analysis Zones (TAZ's) used as the units of analysis in four-step models are also—in many cases—too geographically large to effectively analyze walking trips. In addition, four-step models generally do not consider local land use and built form variables (which can be crucial determinants of transit use), and are incapable of accounting for the impacts of residential self-selection—such as occurs when transit users choose to live in TOD's *(3, 4)*.

Direct Ridership Models (DRM's), also known as off-line models, have recently come to prominence as an alternative. DRM's predict ridership in a single step using multiple regression analysis, based on regional, station-area and proposed transit service characteristics *(3, 5)*. In a DRM, any factor with an empirical relationship to transit use can be used to predict ridership *(3, 6)*. DRM's require actual transit ridership data, but do not require that all aspects of the utility of choosing a given transit option be explicitly considered—or even known. For example, a DRM can account for the frequently observed, yet incompletely understood tendency of rail transit lines to attract somewhat higher ridership than otherwise similar, bus-based services. The "rail bias" can be implicitly considered by the inclusion of ridership data and modal variables from rail and bus transit modes. Lacking the trip origin-destination specificity of other modeling techniques, DRM's are generally considered sketch-planning tools—used for a first look at proposed lines or to weigh the relative impacts of different options *(3)*. Within the bounds of these limitations, a growing body of research shows strong potential for DRM's to predict the ridership of proposed transitways based on realized physical, social and economic characteristics. Lane, DiCarlantonio and Usvyat, in a broad analysis of existing commuter rail and light rail lines in six regions of the United States, found their DRM approach predicted actual ridership with a high degree of accuracy *(7)*. Even so, little research to date has employed direct ridership modeling to analyze the ridership impacts of public policies—such as TOD-friendly zoning, low minimum parking standards (or maximum parking standards), parking pricing, employer-provided transit benefits, and bicycle and pedestrian infrastructure provision—thought to promote transit use.

Direct ridership modeling allows ridership predictions for proposed transitways on the actual ridership of well established, existing lines *(3)*. In 2003, Walters and Cervero were able to predict station-level ridership for a proposed extension of the Bay Area Rapid Transit (BART) system in the San Francisco Bay area. By including both existing BART rapid transit stations and Caltrain commuter rail stations, they were also able to predict the ridership impacts of different rail technologies *(8)*. Kuby, Barranda and Upchurch were able to estimate a single model to explain average weekday boardings for 268 light rail stations in nine markedly different cities across the United States. Notably, their results pointed to land use, regional accessibility and bus connections as important predictors of ridership, along with socioeconomic factors, park-and-ride access and regional centrality. Their model achieved an impressive R^2 value of 0.727, demonstrating the power of the DRM approach *(6)*.

Transit-Supportive Public Policies

The transportation and urban planning literature broadly recognize the strong influence of factors other than transit service and frequency characteristics on transit use patterns. In a study of 265 urban areas across the United States, Taylor, Miller, Iseki and Fink find that a majority of observed variation in per capita transit use rates can be explained by a mix of regional geography, metropolitan economy, population and highway system characteristics. In other words: most of the variation in transit use can be accounted for without even considering transit systems themselves *(9)*. Some of the variables considered in this study—such as total metropolitan population or percentage of Democratic voters—are beyond the control of municipal and regional policy. However, the study also suggests several non-transit system variables that are directly influenced by local and regional public policy, such as population and employment density in transit service areas, and parking supply *(9)*.

Transit-Oriented Development

Attempts to increase transit use through means other than transit system and/or service changes frequently revolve around Transit Oriented Development (TOD). TOD seeks to retrofit transit-friendly built forms onto previously automobile-dominated areas, generally through some combination of high-density housing development, mixed land uses and connected, pedestrian-friendly street environments *(10-12)*. The potential for TOD to increase transit mode shares—along with important limitations to that potential—has been established for decades. Based on early 1990’s data, Cervero found that San Francisco Bay Area residents of dense, compact TOD’s were more likely than others to commute by rail, but that “The strongest predictors of whether station-area residents commuted by rail was whether their destination was near a rail station and whether they could park for free at their destination” *(13)*. Support for the effectiveness of alternative development patterns’ ability to alter travel behavior is not unanimous—Giuliano finds that land use policies are incapable of major travel-behavior impacts *(14)*, while Crane finds the evidence inconclusive *(15)*—but the bulk of the literature appears to find some positive evidence.

Most research on TOD has traditionally been conducted at the local level, focusing on individual developments or groups of developments. Some recent research also considers TOD at the regional level. The importance of transit-accessible destinations is echoed by Tilahun and Fan in a 2014 study of future growth scenarios in the Twin Cities region. Their research found that concentrating future housing development in transit-served areas would have a significant, positive impact on transit-based employment accessibility (thus making the transit system more useful), but that concentrating future employment growth near transit would have a larger positive impact and that the greatest benefit would come from concentrating both *(16)*.

Public sector policy decisions have an important role to play in promoting TOD. A variety of researchers find latent, pent-up demand for TOD, along with evidence that automobile-oriented zoning and other development regulations hinder developers from pursuing transit oriented projects *(17-20)*. In addition, Levine and Frank find a relative undersupply of compact, transit-friendly development in the highly-sprawled metropolitan Atlanta region when compared with metropolitan Boston based on residents' preferences *(21)*. In recent research on Twin Cities region, Fan and Guthrie find regulatory structures designed to limit density, separate uses and ensure universal automobile access to be an important obstacle to TOD *(17)*.

Parking Policy

Parking supply and/or pricing can have major effects on travel behavior, and are also in large part determined by public policies. Near-universal minimum off-street parking requirements designed primarily to ensure uninterrupted motor vehicle access (rather than to ensure optimal transportation system performance or highest and best use of urban land, etc.) mean that motorists enjoy free parking for 99% of trips—a subsidy estimated to be greater than free fuel *(22)*. Willson finds that excessive workplace parking requirements impact urban form, transit demand and ultimately transit service. Willson also finds potential for transit providers to benefit from helping shape reformed parking standards *(23)*. Shiftan and Golani also find, based on survey data, that downtown parking reductions and price increases, along with other constraints on automobile use would be more likely to change downtown-bound travelers' mode choices than their destinations *(24, 25)*.

The literature suggests that the interrelationship of parking policy and automotive travel demand is often not well understood and/or seen as important by the local planners who craft parking policies and implement them on a project level *(22)*. In a survey of planners from 138 California local governments, Willson finds "that the most common response to a question about workplace parking issues was that there were *no* important issues. The next most frequent response was parking *undersupply*." (Emphasis in original.) Planners gave these responses despite significant empirical evidence that an oversupply of parking is the most common situation *(23)*. The same survey also finds that planners most commonly cite "ensuring an adequate supply of parking" as the primary consideration in parking policy, demonstrating a general lack of critical consideration of the transportation system impacts of parking policy. Willson further finds that the risks of under-building parking (such as neighborhood spillover, congestion, perceived excessive density, etc.) tend to be more clearly perceived by planners (and neighborhood groups) than the risks of overbuilding parking (such as foregone tax revenue, excessively low density, poor urban design and pedestrian environment, increased VMT and difficulty in providing transit) *(23)*. To deal with oft-raised concerns over neighborhood spillover parking, Shoup suggests the creation of "parking benefit" districts, in which revenues from market-priced on-street parking would be directed to benefit the local community. Shoup contends that revenues from fair-market pricing of curbside parking could exceed those from residential property taxes *(26)*. These findings suggest significant room for public-policy improvement in crafting parking requirements with the goal of transit-friendly communities in mind.

Employer Commute Benefits

Employers' benefits packages can also influence commuters' mode choices. Particularly for downtown workplaces—often those for which transit is most likely to offer a viable commute option—employers frequently provide significant parking subsidies which insulate individual employees from the full cost of driving to work. As far back as 1992, Shoup and Willson proposed requiring employers that provide parking benefits to also offer employees a transit pass or cash commute allowance of equal value. They predicted that implementing such a policy in downtown Los Angeles would reduce automotive commuting by 17% while leading to a 67% increase in transit use *(27)*. Acting along similar lines, by offering both employees and students subsidies for carpooling and transit passes as an alternative to parking passes, the University of Washington achieved a 16% reduction in motor vehicle trips to campus, along with a 35% increase in transit trips and a 21% increase in carpools *(28)*. Dill and Wardell find that employers in Portland, Oregon who participate in TriMet's discounted employee pass program have transit mode shares seven percentage points higher regardless of location, twelve percentage points higher downtown and five percentage points higher outside downtown, even when controlling for proximity to LRT and bus stops, employer characteristics and built form characteristics *(29)*. Su and Zhou reach generally similar conclusions for transit benefits in Seattle, Washington, as well as significant impacts for higher SOV (and lower HOV) parking prices *(2)*.

Walkability/Bikeability

Street environments surrounding transit stations can have profound impacts on transit use behavior as well. In a study of Saint Louis Metrolink riders, Kim, Ulfarsson and Hennessy find that perceived security as well as availability and convenience of bus connections had significant impacts on light rail users' access modes *(30)*. Schwanen and Mokhtarian found that neighborhood environmental factors (such as land use mix, density and pedestrian environment) had a greater impact on commute mode choice than residents' neighborhood type preferences, especially in transit-unfriendly environments. According to their research, "Although mismatched suburban residents may be more inclined to use transit than their matched neighbors, many may feel they have no choice […] but to commute by personal vehicle" *(31)*. Cervero finds that local neighborhood-level land use and urban design factors have significant impacts on mode choice—even controlling for modal travel-time differences. In a study of household travel survey data from Montgomery County, Maryland, density, mixed uses and the prevalence of sidewalks all predicted significantly higher rates of transit and nonmotorized travel *(32)*.

Cervero also contends that improving pedestrian and bicycle conditions around transitway stations could have important long-term mode shifting impacts even if the immediate effect is primarily a shift in transit users' access modes from park-and-ride to walk/bike-and-ride. Reduced demand for park-and-ride access would allow transit providers to redirect resources from parking provision to actual transit operations (leading to more attractive services), and reduced use of station area land for parking would ease the promotion of transit-oriented development (leading to increased trip origin and destination densities in station areas) *(33)*.

Summary

Encouraging mode shifts from automobiles to transitways through policies that look "beyond the rail" is a complex problem which traditional travel demand modeling techniques are ill-equipped to solve. Multiple areas that are already heavily influenced by local public decision-making—including transit-oriented development, zoning, parking policy, employer commute benefits and pedestrian- and bicycle-oriented design—appear to present significant opportunities to encourage just such mode shifts if the policies guiding them can be coherently retooled with mode shifting as a goal. Indeed, a review of the literature reveals enough public policy hindrances to auto-transitway mode shifts that achieving the full mode shifting potential of transitways may simply be impossible without beyond-the-rail policy tools. Despite the complexity involved, direct ridership modeling techniques offer a robust method for analyzing the ridership impacts of local public policy decisions based on actual results from existing, well established transitways..

METHODS

The research approach hinges on the use of station-level boarding data to allow for a model sensitive to localized, station area conditions. Unlike provider- and mode-level ridership data, no national source of station level boarding data exists. As such, the first phase of data collection involved contacting transit providers in study regions to request data. The authors enjoyed an extraordinary degree of cooperation in this phase: every provider contacted eventually provided ridership data. Figure 1 shows the regions and modes included in the research.

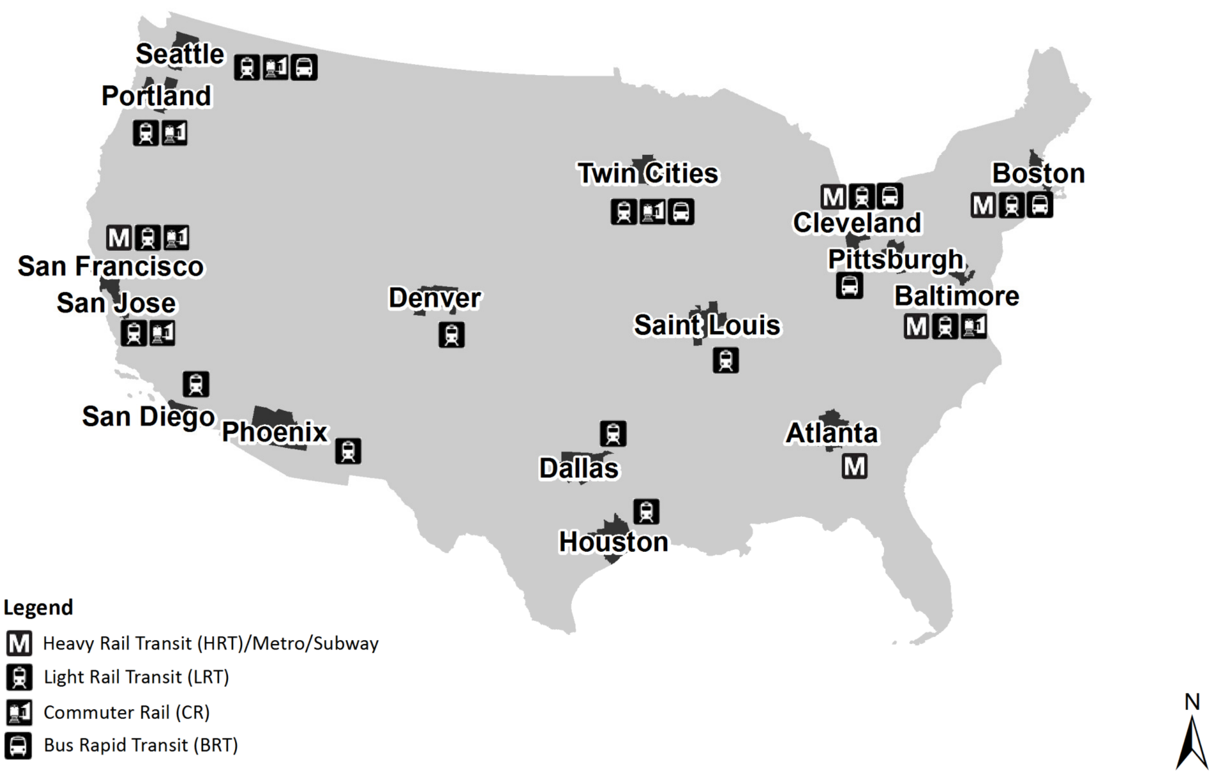

FIGURE 1 Study regions and modes

Ridership Data Issues

Despite the willing assistance received from transit providers, several problems with ridership data arose. First of all, there is no universal standard for measuring the ridership of fixed-guideway transit services. Light rail, bus rapid transit and commuter rail systems tend to track average weekday boardings—the number of passengers who board a train or bus at a given stop on an average weekday. Ridership may be counted directly using Automatic Passenger Counters (APC's) or estimated using manually conducted sample counts. If performed properly, either collection method provides a relatively close measure of unlinked trips. Heavy rail rapid transit systems, however, tend to track station entries. These fully grade-separated systems generally use barrier-based fare collection systems (such as turnstiles), with neither additional fares nor transfers required between lines. As a result, this method of ridership data collection measures linked trips. For example: a Twin Cities transit user wishing to travel via light rail from the University of Minnesota to MSP International Airport would board a westbound Green Line train on campus (one boarding), alight at Downtown East and board a southbound Blue Line train (two boardings). A MARTA user in Atlanta wishing to travel from Georgia State University to Hartsfield-Jackson International Airport, however, would enter the system at Georgia State Station (one station entry), board a westbound Blue or Green Line train, alight at Five Points and transfer to a southbound Gold or Red Line train without ever leaving the station. As a result, only the initial station entry is recorded in ridership data, producing an undercount of ridership at transfer stations relative to the methods used by LRT, BRT and commuter rail.

Also, in addition to a number of modern "New Start" light rail lines, this study includes four regions with legacy light rail systems converted and upgraded from survivors of their cities' original streetcar systems—Boston (Green Line), Cleveland (Shaker Rapid), Pittsburgh (the T) and San Francisco (Muni Metro). These systems are hybrids—with full grade-separation and subway- or light rail-style stations in the central business district, and more or less traditional streetcar operations further out. Due to somewhat older vehicles and large numbers of rudimentary median or even curbside stops, only the Massachusetts Bay Transportation Authority and the Greater Cleveland Regional Transit Authority were able to provide reliable boarding data for their entire light rail systems. San Francisco Muni was only able to offer station entries for their Market Street subway stations, while the Port Authority of Allegheny County in Pittsburgh does not track light rail ridership at the station level.

Policy data

As with station-level ridership, no national data source for transit-supportive public policies exists. In fact, even individual municipalities seldom have a single inventory of such policies. As a result, transit supportive public policies required original data collection. Data collection initially took the form of an online survey distributed to planning staff in cities containing study stations. Despite multiple contacts and reminders, the authors failed to obtain a sufficient response rate (Less than one fifth of the cities in our other data) from the survey.

To allow the research to proceed, the authors manually coded remaining cities by using the original survey instrument as an audit conducted by a member of the research team. The survey instrument collected data on:

- Land use policy
- Pedestrian/bicycle infrastructure policy
- Street design standards
- TOD funding/promotion policy

- Affordable housing policy
- Transit system fare policy
- Policy implementation mechanisms

To obtain clear, unambiguous answers, questions were phrased as a binary policy present versus policy absent choice, for example: "Does the city allow higher densities in stations areas?" or "Does the city have policies promoting the construction of new affordable housing in station areas?". Policies focus on basic standards for public facilities (such as calling for sidewalks along all streets) are considered present if they apply either specifically to station areas or generally to the city as a whole. Policies dealing with the allocation of public resources or types of development (such as affordable housing promotion or zoning) are only considered present if they focus specifically on station areas. For example, a city wide policy requiring sidewalks on all streets would be coded as present, as would a policy promoting affordable housing in station areas, while a general, city wide policy of promoting affordable housing would be coded as absent.

Google Places

The authors also downloaded "places" data in bulk from Google Maps. Google places are the source data for the business, institution and other destination placemarks that appear in Google Maps when zoomed in to a relatively small geographic extent. Specifically, the authors downloaded counts of places, both in total and by type within a 100M radius of each transitway station included in the data. The authors employ a relatively small radius because Google sets a bulk download limit of 60 places per central point/station; a larger radius would artificially reduce variation in the count of places by pushing more stations past 60 places. Google places provide a measure of neighborhood activity with much finer geographic scale than is available from other data sources.

Approach

The authors propose that transitway ridership, at the station level, is largely locally determined by realized station area conditions, such as the built environment and demographics. However, there also exist a wide variety of public policies which seek to influence those realized conditions, such as zoning codes, street design guidelines, housing policies, etc. These policies may impact transitway ridership indirectly by influencing the realized station area conditions which in turn influence ridership. There may also be an interaction effect between policies and station area conditions by which the presence of a consistent policy reinforces the impacts of transit-friendly station area conditions or mitigates the impact of transit unfriendly conditions.

The research employ a Direct Ridership Model (DRM) to predict transitway boardings at the station level as a function of transit-supportive public policies while controlling for transit service and regional characteristics and station area built environment and social characteristics. As described by Cervero (2006), DRM's employ multiple regression to predict ridership in a single step based on any set of predictors the modeler deems appropriate or is interested to explore the specific effects of.

RESULTS

Table 1 shows the results of the ridership model. The authors initially estimated a combined model including all 850 observations. Suspecting an interaction effect between Parking policy and Google places due to counter-intuitive results, the authors divided the data just below the

TABLE 1 Ridership models

			Combined			*<50 Est.*			*≥50 Est.*		
	Response Variable:	**Observations**	850			406			444		
	Boardings	**Pseudo R^2**	0.74			0.67			0.78		
	Explanatory		*β*		*IRR*	*β*		*IRR*	*β*		*IRR*
Policies	**Pro-sidewalk policy (binary)**		0.2289		1.2572	0.2462		1.2791	0.2461	*	1.2790
	Pro-density policy (binary)		-0.0575		0.9441	0.1204		1.1279	-0.2117		0.8092
	Pro-affordable housing policy (binary)		0.2861	**	1.3312	0.0915		1.0958	0.3794	***	1.4615
Built Environment	**Number of establishments (count)**		0.0109	***	1.0109	0.0118	**	1.0118	0.0549	**	1.0564
	Residential density (housing units/acre)		-0.0026		0.9975	-0.0017		0.9983	-0.0046		0.9954
Station Characteristics	**HRT (binary)**		1.0425	***	2.8362	1.0837	***	2.9555	1.0066	***	2.7363
	BRT (binary)		-0.8989	***	0.4070	-1.1419	***	0.3192	-0.8790	***	0.4152
	CR (binary)		-0.5180	*	0.5957	-0.6940	**	0.4996	-0.2305		0.7941
	Legacy system (binary)		-0.0546		0.9469	-0.3465		0.7072	0.1013		1.1066
	Number of lines (count)		0.3519	***	1.4218	0.4300	***	1.5372	0.2879	***	1.3337
	One-direction station (binary)		-0.7969	***	0.4507	-0.8327	***	0.4349	-0.7360	***	0.4790
	Terminal station (binary)		0.5000	***	1.6487	0.7391	***	2.0941	0.2763	**	1.3183
	Park and ride (binary)		0.1269		1.1353	0.1806	*	1.1979	-0.0888		0.9150
	Distance from CBD (kM)		-0.0188	***	0.9814	-0.0121	***	0.9880	-0.0234	***	0.9769
	Distance from next station (kM)		0.0816		1.0850	0.0497		1.0509	0.1490	*	1.1606
Social Characteristics	**Median income ($1K)**		-0.0004		0.9996	0.0000		1.0000	0.0003		1.0003
	% 1-person households		-0.1537		0.8575	0.6341	*	1.8853	-0.3974	**	0.6721
	% population < 18 yr.		-1.4274	***	0.2399	-0.7290		0.4824	-2.1035	***	0.1220
	% population ≥ 65 yr.		-0.5324	*	0.5872	-1.5189	**	0.2190	-0.2882		0.7496
	% minority population		-0.1718		0.8421	-0.1603		0.8519	-0.2133		0.8079
	% foreign born residents		0.9561	***	2.6016	0.9316	*	2.5386	1.0602	***	2.8871
	% households where workers > cars		1.0443	***	2.8415	1.2660		3.5467	0.8810	***	2.4133
	Constant		6.1176			5.5933			3.8157		

*p < 0.1; **p < 0.05; ***p < 0.01

median of 54 places into two models: one for stations with less than 50 Google places in its immediate environs and one for stations with greater than or equal to 50 such places.

The final models employ Poisson regression, with boardings as the response variable and the following explanatory variables:

- Pro-sidewalk policy—Dummy variable indicating the presence of a policy explicitly calling for sidewalks on all streets either in station areas or generally.
- Pro-density policy—Dummy variable indicating the presence of a policy allowing for higher residential and/or commercial densities in station areas than elsewhere in the city. To yield a value of 1, the policy in question must have a specific station area focus.
- Pro-affordable housing policy—Dummy variable indicating the presence of a policy calling for the preservation of existing affordable housing and/or the construction of new affordable housing in station areas. To yield a value of 1, the policy in question must have a specific station area focus.
- Number of establishments—Count of Google places within a 100M radius of the station. Included as a measure of activity in the station area.
- Residential density—The residential, in dwelling units per acre, of the census block group containing the station.
- HRT, BRT, CR—Dummy variables identifying the transitway mode serving the station. LRT is omitted as the reference.
- Legacy system—Dummy variable identifying stations on a legacy rail system operated by a transit provider that never abandoned rail transit. For example, San Francisco's Muni light rail and Caltrain commuter rail services are legacies; the Bay Area Rapid Transit system (BART) is not. Included due to a frequent lack of self-conscious transit-supportive policies in cities with legacy rail systems, due to transit-oriented environments being unremarkable in such places.
- Number of lines—The number of transitway lines serving the station.
- One direction station—Dummy variable identifying stations only offering service in one direction, generally where a transitway employs a one-way pair alignment.
- Terminal station—Dummy variable identifying the terminal of a transitway.
- Park-and-ride—Dummy variable identifying stations with commuter parking.
- Distance from CBD—The airline distance, in kilometers, from the station to the transitway station closest to the heart of the central business district. Included as a measure of centrality while providing more information on metropolitan radius than a simple city/suburb dummy variable.
- Distance from next station—The airline distance, in kilometers, from the nearest other transitway station. Included to account for station-level ridership differences which may appear due to the division of transit demand among more or fewer stations.
- Median household income, % Single-person households, % of residents under 18, % of residents age 65 and over, % minority population, % foreign born, % of household where workers > cars—Measures of social conditions in the census block group containing the transitway station.

In the model for stations with less than 50 establishments in their immediate surroundings, none of the policy variables are significant, indicating there is a minimum level of station area activity required for the transit-supportive policies considered to have a discernable effect on transitway boardings. The count of nearby establishments is significant and positive, indicating station area activity has a positive relationship with ridership even without the critical mass needed for transit supportive policies to have significant effects.

Nearly all the transit station characteristics variables are at least marginally significant, including park-and-ride, which was insignificant in the combined model. While HRT has a strongly positive coefficient, BRT and commuter rail are both strongly negative. (All modes are compared to LRT.) BRT has a particularly strong negative coefficient, attracting less than one third as many boardings per station as LRT, all else equal. In addition, the model predicts that ridership drops roughly 1.2% for every kilometer of distance from the central business district.

Of the social variables included, only percent one-person households, percent of the population age 65 and older and percent foreign born residents are significant. In a notable difference from earlier models, percent of households with more workers than cars is insignificant.

In the model for stations immediately surrounded by at least 50 establishments, a pro-sidewalk policy is marginally significant and a specifically station-area focused pro-affordable housing policy is highly significant. Both have relatively strong positive coefficients, as well. A pro-sidewalk policy yields a 28% increase in boardings, while a station-area focused pro-affordable housing policy yields a 46% increase. The number of establishments is still significant, and actually has a more strongly positive coefficient, lending support to the idea of an interaction effect between station area activity and transit-supportive policies.

Only HRT (with a strong, positive coefficient) and BRT (with a strongly negative coefficient) are significant among transit modes. The insignificance of commuter rail may stem from high-activity commuter station areas tending overwhelmingly to be located in central business districts, with consequently heavy use. Park-and-ride is also no longer significant as a predictor of ridership, indicating that the absence of a park-and-ride facility is not a significant detriment to transitway use in station areas with sufficient surrounding activity.

Among the social variables, percent of one person households remains significant and positive. Percent of the population under age 18 is now significant, with a strongly negative coefficient potentially reflecting lower ridership in single-family residential areas. Percent foreign born residents remains significant and strongly positive. In this model, percent of households with more workers than cars is highly significant, with a strongly positive coefficient. The model shows that every percentage point increase in households with low automobility yields a 2.4% increase in transitway ridership.

Table 2 shows standardized coefficients for the final policy model for station areas with at least 50 establishments. The strength of the two significant modal dummy variables (positive for heavy rail, negative for BRT) is striking. These variables compare their respective modes to light rail. It is likely that some degree of modal bias is reflected in the results. However, on must bear in mind that the relationship between mode and ridership may simply reflect the selection of transit technologies based on predicted demand. A common pattern among regions studied is to use rail for their highest-demand corridors, complemented and augmented by BRT on corridors with more moderate demand—a practice which reflects Twin Cities transitway plans as well.

Another striking result is the relative strength of a station area focused pro-affordable housing policy. It is the fourth strongest predictor of ridership in the model, stronger even than the number of households with more workers than cars. Pro-affordable housing policy is also significantly stronger than pro-sidewalk policy.

TABLE 2 Standardized coefficients, ≥50 establishments model

Relationship with Ridership	Variable	Coefficient	Significance
Strongest	HRT (binary)***	1.434	***
	Number of lines (count)***	1.280	***
	% foreign born residents***	1.179	***
	Pro-affordable housing policy (binary)***	1.144	***
↑	Distance from next station (kM)*	1.121	*
	% households where workers < cars***	1.116	***
	Number of establishments (count)**	1.097	**
+	Terminal station (binary)**	1.076	**
	Pro-sidewalk policy (binary)*	1.057	*
	Legacy system (binary)	1.049	
	Median income ($1K)	1.011	
	% population ≥ 65 yr.	0.971	
	Park and ride (binary)	0.967	
	CR (binary)	0.966	
−	Pro-density policy (binary)	0.953	
	Residential density (housing units/acre)	0.951	
↓	% minority population	0.949	
	% 1-person households**	0.919	**
	% population < 18 yr.***	0.818	***
	One-direction station (binary)***	0.725	***
	Distance from CBD (kM)***	0.698	***
Strongest	BRT (binary)***	0.659	***

Model Predictions

As a hypothetical example of the implications of the model results, the following section presents predicted boardings for archetypal stations in the data. Computing marginal effects for different transit-supportive policies while holding other variables constant can illustrate the real-world impacts of the results. Figure 2 shows model predictions for two typical light rail stations, one with less than 50 surrounding establishments, one with at least fifty. Other than this difference, and the policy variables being manipulated, these stations are absolutely typical of the sample: other variables are held at their median/modal values

In every case, the typical station with less than 50 surrounding establishments attracts 819 average weekday boardings. No policy variable are significant in the relevant model: it predicts no change in ridership based on the presence of transit-supportive policies.

With no supportive policies, the typical station with at least 50 surrounding establishments attracts 1,006 average weekday boardings. Predicted boardings increase to 1,287 with an explicit, pro-sidewalk policy and to 1,471 with a station area-focused pro-affordable housing policy. The presence of both policies increases the predicted number of boardings to 1,881, nearly double the predicted boardings with neither policy and more than double the boardings predicted for the station with less than 50 surrounding establishments.

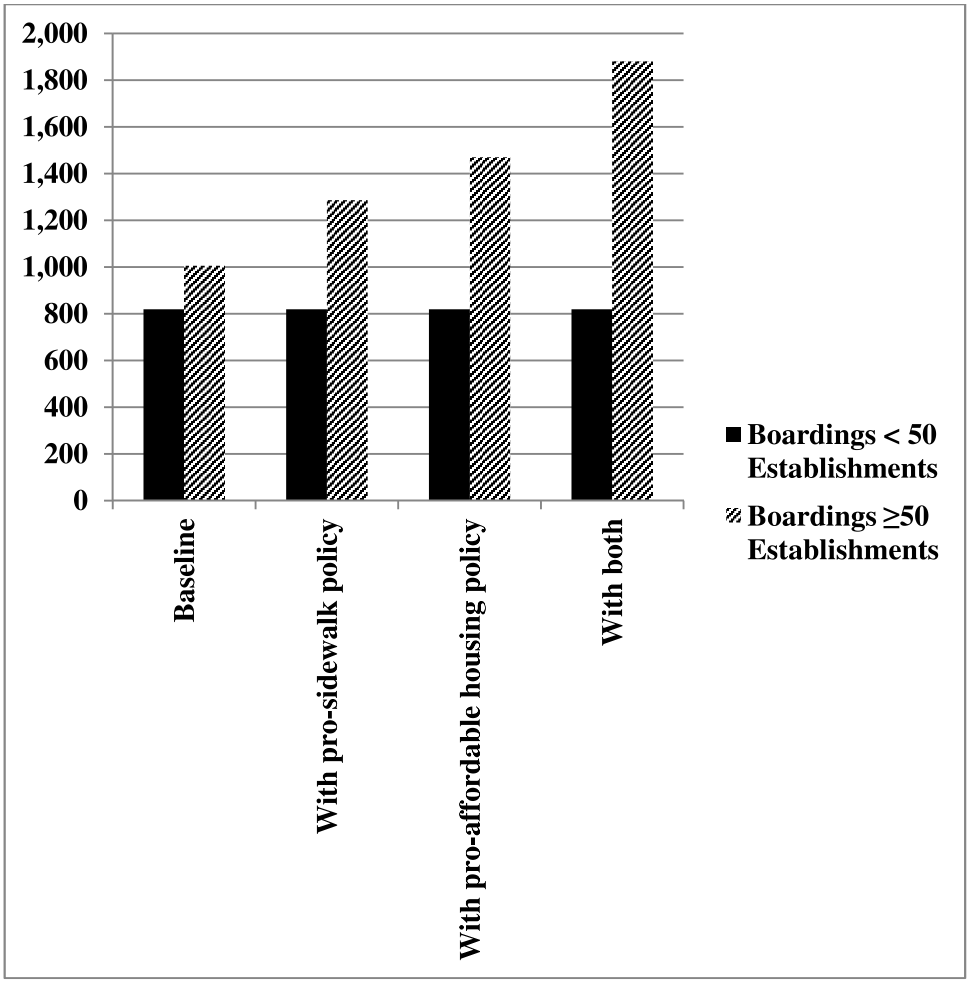

FIGURE 2 Model predictions

CONCLUSIONS

Under the right circumstances, transit-supportive public policies matter. While the actual built environment is crucial, the models show that policies supporting affordable housing and pedestrian infrastructure consistently increase transitway ridership *if* they are applied in a station areas with a sufficient level of activity. The dramatic difference in results upon splitting the final models by the number of surrounding establishments illustrates the strength of the interaction between policies and station area activity.

It is particularly important to note the strength of the positive relationship between station area-focused pro-affordable housing policies. This suggests something of a departure from common planning practice, at least as far as planning for increased ridership goes. Consideration of transit access in siting affordable housing is not uncommon, but the rationale for it tends to be one of social equity—an attempt to improve the lives of the specific individuals who will live in such housing. This research shows that supporting the provision of affordable housing in station areas enhances transit system efficiency as well. This is an important finding to bear in mind in the station area planning process, especially considering that affordable housing can be significantly more fraught with controversy than aspects such as pedestrian infrastructure.

The link between surrounding area destinations and pro-sidewalk policies appears fairly straightforward: policies promoting sidewalks matter if (and *only* if) there are actually things to walk to. The link between pro-affordable housing policies and nearby destinations may, at first, seem less clear. On further consideration, one might contend that station area focused pro-affordable housing policies play a significant role in encouraging transitway usage *given* sufficient opportunity to accomplish one's general daily needs in the station area, as well as affordably live there. Put simply, no matter what level of regional mobility or employment access living near a transitway station offers, if one cannot reach a grocery store, daycare center, etc. without a car, one is likely to own one, regardless of the financial strain that may come with it. Such a conclusion would also follow from the finding of a strong positive relationship between households with fewer cars than workers and transitway ridership.

The results recommend station-area focused affordable housing promotion and explicit pro-sidewalk policies in sufficiently active environments as a way of increasing transitway ridership. This is not to say, however, that such policies are not worth pursuing for station areas with more sparse surroundings. The models do not show that affordable housing- and sidewalk-promoting policies are worthless in areas with relatively few potential destinations nearby, but that they are, by themselves, insufficient in such areas. Planning to increase transitway ridership in lower activity areas should focus both on supportive policies and on development of the neighborhood-scale commercial centers that make them relevant.

The modeling results speak to the power individual municipalities have to determine the degree of success transit investments serving them will have. They also speak to the limitations of those policies: the basic, necessary conditions of the built environment for the creation of transit-supportive neighborhoods. The findings lay out an agenda for cities served (or planned to be served) by transitways to both align their municipal policies with the goal of promoting transitway ridership, and to set about coaxing their built environments into the needed neighborhood-scale form as well.

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