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Exploring Strategies for Promoting Modal Shifts to Transitways

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16. Abstract (Limit: 250 words)

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.

This study explores the impacts of travel time, travel cost, and population density on mode choice, using the 2010 Travel Behavior Inventory. We found a monetary value of in-vehicle travel time of $17.5/hour and a transfer penalty of $10, equivalent to 35 minutes in-vehicle travel time. Density, especially at destinations, has important effects, but travel time is the key to promote the shift to transit.

The research also employs a Direct Ridership Model (DRM) to predict boardings at the station level as a function of transit-supportive policies. We find that station-area focused policies promoting affordable housing and 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, measured as the number of Google places within 100 meters.

Based on our results, we 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. We recommend strengthening pro-affordable housing policies and pro-sidewalk policies in Twin Cities station areas, supporting and encouraging 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 as the regional transitway system expands.

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Exploring Strategies for Promoting Modal Shifts to Transitways

Final Report

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Executive Summary

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.

This study explores the impacts of travel time, travel cost, and population density on mode choice, using the 2010 Travel Behavior Inventory. It focuses on the competition between transit and personal vehicles, in particular, Drive Alone, Shared Ride, Transit with Drive access and Transit with Walk access. We found that in the Twin Cities and collar counties, the monetary value of in-vehicle travel time is about $17.5 per hour and transfer penalty is valued at about $10, or equivalent to 35 minutes of in-vehicle travel time. Furthermore, for Drive Alone and Shared Ride, destination population density is more important than origin population density, especially for Shared Ride. Density has a critical impact on the choice of transit but it did not show an influence on the modes of access to transit. Travel time is the key to promote the shift to transit.

The research also directly examines transitway ridership at the station level. Transitways have a ridership impact of their own, but their stations exist in an environment of municipal policies that may not aim to maximize transitway use and often aim to maximize automotive mobility. We explore the impact of municipal policies on transitway ridership through a national study of the Twin Cities and 15 peer regions identified by the Metropolitan Council, seeking to answer the research question: What role transit-supportive public policies implemented around transitway stations play in boosting transitway ridership.

To enable the fine-grained consideration of local, station area conditions, we employ a Direct Ridership Model (DRM) to predict boarding at the station level as a function of transit-supportive policies, controlling for built environment, transit service and socioeconomic characteristics. We find that specifically 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, measured as the number of Google places within 100 meters. All else equal, a typical light rail station in such an area will have nearly twice as many boardings on an average weekday if the city it is located in has such policies.

Based on our results, we 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. We recommend strengthening pro-affordable housing policies and pro-sidewalk policies in Twin Cities station areas, supporting and encouraging 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 as the regional transitway system expands.

Chapter 1: Introduction

“Taking cars off the road” is a familiar phrase in public statements of support for transitway investments. In the popular imagination, one selects a congested route, lays track and drivers proceed to directly substitute transit trips for driving. Transitways’ proven ability to attract choice riders is undeniably compelling, but the reality of their mode-shifting impacts can be complicated. Some of a transitway’s users do directly replace auto trips with transit trips, others used transit to begin with, and still others make trips they would not have made at all absent the transitway. The relative sizes of these groups can vary widely based on transitway alignment, service and surroundings.

This research investigates the mode-shifting impacts of transitways through three distinct parts. Chapters 1-4 are an in-depth literature review of strategies to maximize the mode-shifting impacts of transitways. It synthesizes applicable findings of *TCRP Report 95: Traveler Response to Transportation System Changes* to the Twin Cities region, as identified by regional transit-planning stakeholders, and offers case studies of efforts to shift trips to transit in Chicago, Illinois and Ottawa, Ontario.

Chapters 5-8 empirically examine mode choice in the Twin Cities region, focusing particularly on competition between automobile and transit. Based on the Metropolitan Council’s 2010 Travel Behavior Inventory, this section presents a mode choice model describing the characteristics of trips, their origins and destinations that appear as important predictors of transit use.

Chapters 9-13 look specifically at the transit side of the mode choice equation, in a national-scope, station-level ridership model. This section focuses on explaining transitway boardings as a function of transit service type, surrounding built environment and social conditions, as well as transit-supportive municipal policies, such as transit-oriented development-friendly zoning, uniform provision of pedestrian infrastructure and the focusing of affordable housing development in station areas.

Chapter 2: Literature Review

Encouraging modal shifts away from driving is a common goal of transitway investments. Examples exist around the nation (and the world) of metropolitan regions working towards—and achieving—significant mode shifts from automobile to transit. Transitways generally play an important role in such shifts, but the construction (or improvement) of transitways alone is but one of a complex mix of strategies employed by the most successful regions. As transitway development accelerates in the Twin Cities, interest is growing in public policies to augment the inherent mode-shifting impacts of simply building transitways.

The following chapter synthesizes the current state of knowledge about strategies for encouraging automotive-to-transit modes shifts through a review the transit implications of *TCRP Report 95: Traveler Response to Transportation System Changes*. *TCRP 95* offers a broad-based look at common strategies for encouraging drivers to switch to transit. Based on the feedback of planners in the Twin Cities, our synthesis focuses on the following eleven strategies:

- Transit scheduling and frequency,
- Bus routing and coverage,
- Transit pricing and fares,
- Park and ride,
- Parking pricing and fees,
- Parking management and supply,
- Road pricing and HOT lanes,
- Land use and site design,
- Transit oriented development,
- Pedestrian and bike facilities, and
- Employer and institutional Travel Demand Management (TDM) strategies.

In addition to these qualitative examples of transit use promotion strategies, this chapter will also examine the shortcomings of traditional, regional travel demand models and alternative analysis methods for quantifying the potential mode-shift impacts of various strategies and mixes of strategies. Alternative analysis techniques examined include Direct Ridership Models (DRM's) and post-processing of ridership model results.

Finally, this chapter will present two case studies of transit promotion efforts in Chicago, Illinois and Ottawa, Ontario. The case studies will take a deeper look at the strategies employed in two very different regions. In Chicago, due to the presence of an extensive legacy rail system, as well as numerous areas with residual transit-oriented built forms, transit use promotion strategies focus on judicious transit improvements and "beyond the rail" strategies to encourage transit use. In Ottawa, considerably more recent metropolitan growth (and the resulting automobile-oriented built form) presents a different planning problem: transit use promotion efforts in Ottawa center around a major buildout (and continuing improvements) of transitway infrastructure and regional land use policies encouraging the concentration of regional employment around transitway stations. These two case studies offer detailed parallels to the differing problems of renewing the relevance of transit to urban areas developed in the original transit era, and of retrofitting quality transit to suburban areas developed in the automobile era.

Chapter 3: Review of Transit Use Promotion Strategies

Common strategies to encourage mode shifts to transit are often seen as taking two basic forms: strategies to make transit use more attractive (such as service frequency increases or transit-supportive land use policies) or strategies to make driving less attractive (such as parking supply reductions or reassignment of general-purpose lanes to exclusive transit use). However, all have one overriding intent: to alter the relative utility of transit and driving so that a significant number of drivers choose to use transit instead. The following section offers a broad review and specific examples of efforts to achieve that alteration and encourage those choices.

The Transit Cooperative Research Program's *Report 95: Traveler Response to Transportation System Changes* is a handbook seeking to provide "comprehensive information on travel demand effects of alternative urban transportation policies, operating approaches and systems, and built environment options" (Pratt, 2013). First published in 1981, and now in its third edition, *TCRP 95* is one of the broadest resources available to inform the planning of alternative transportation systems. The following subsection distills and synthesizes the specific findings of *TCRP 95* most relevant to goal of encouraging mode shifts from automobiles to transit.

3.1 Transit scheduling and frequency

There are two major reasons for scheduling and frequency changes: quality of service and cost effectiveness. Generally those objectives are opposite and mutually exclusive. There are several different types of scheduling changes: frequency changes (a transit agency increases or decreases the number of scheduled trips), service hour changes (a transit agency increases or decreases the hours in which transit service is provided), frequency and fare changes (a scheduling change is provided concurrently with an increase or decrease in price of a trip), combined service frequencies (multiple services are provided, for instance an express route and a normal route operating on the same street), clocked headways, and reliability changes (I. Evans, 2004).

3.1.1 Frequency

Evidence of the ridership impacts of bus frequency changes is mixed, with an elasticity ranging from +0.3 to +1.0, with a historical average of around +0.5. (The elastic response is the percentage change in ridership associated with a 1% change in a particular system characteristic.) A comparison of suburban, urban, and BRT routes in Boston showed that its rapid transit was least affected and a downtown distributor had the most effect in terms of frequency elasticity. Increasing the frequency of a commuter rail service does not have much of an impact on ridership beyond a certain point. In Boston, commuter rail with initial headway greater than 50 minutes showed an arc elasticity of -0.76 while commuter rail routes with initial headway less than 50 minutes displayed an arc elasticity nearly half that, at -0.41 (Ibid.).

3.1.2 Service hours

Service hour changes can attract new ridership by better fitting the schedules of potential users. On New Jersey Transit's commuter rail system, when Sunday service was restored, Sunday ridership reached 1,100 after two years of service on this route, with 5,700 riders typical on a weekday. Santa Clarita Transit started transit sercice on Sunday and increased weekday and

Saturday service hours, contributing to an elasticity of +1.14 from 1992 to 1998. Service hour changes can help attract commuters concerned about missing the last train or bus home (Ibid.).

3.1.3 Frequency changes with fare changes

Using a case study from 1985-1987 in Dallas, it was shown that urban buses (with respect to bus revenue miles) saw a service elasticity of +0.32 with a fare elasticity of -0.35, while suburban express buses showed elasticity of +0.38 and -0.26, respectively. When frequency levels are high, such as in the inner city, riders are more responsive to changes in fare than changes in frequency, whereas riders of lower frequency routes are more sensitive to frequency changes than fare changes (Ibid.).

3.1.4 Combined service frequencies

Combined service frequencies involve offering an express option on a given corridor by overlapping local buses giving travelers a faster option of getting through a given corridor. The highest elasticity is on commuter bus routes from residential areas to central business districts: +0.9. While most travelers within the corridor do not directly benefit from an express route, increased options of speed and accessibility can attract additional ridership (Ibid.).

3.1.5 Clocked headways

Clocked headways is the concept of making regular, reliable transit schedules that can minimize regular travelers' wait time at stations, creating a perception of less wait time. It is important to establish a system that can be easily remembered by riders or easily accessible via internet or at stations in attempts to entice riders to use transit. This is mostly attributed to commuter rail and bus rapid transit which have lower frequencies since higher frequency routes inherently limit users' wait time at stops (Ibid.).

3.1.6 Reliability changes

Improvements in on-time performance are highly valued by riders, and reduce perceptions of travel time. Many riders avoid transit not necessarily on the basis of wait time, but on the perceived wait time which can be dramatically reduced by reliable schedules and frequency. Using a case study of observed buses in London, one line with the most reliable service and one line with the least reliable service, the perceived wait time on the most reliable service was almost half the actual wait time whereas the least reliable service has a perceived time around the same as the actual wait time (Ibid.).

3.2 Bus routing and coverage

Bus routing strategies include creating new bus systems, expanding the existing system by increasing frequencies and coverage, restructuring the existing system, using circulators in high traffic areas, and using feeder lines to serve trunk lines or other mass transit systems. These different methods can produce wildly varying results depending on the city and type of land use on which they are used. Some methods work better in more densely populated urban areas while others achieve better in suburban areas (Pratt & Evans, 2004).

3.2.1 New systems

Completely new bus transit systems in areas previously not served by transit typically achieved passengers per bus mile rates between 0.8 and 1.2 in the first full year of operation, and system usage usually continued to grow during the following years. Examples are limited due to the near ubiquity of basic bus service in all but the smallest communities, but larger cities and college towns appear to achieve the best results with new systems (Ibid.).

3.2.2 Service expansion

Individuals' response to overall service expansion differs from case to case. Individual cases with elasticity as low as +0.3 or over +1.0 are not uncommon, though the typical range of elasticity falls between +0.6 and +1.0. Increases in bus frequency alone result in elasticity averaging +0.5. Off-peak elasticities show greater improvements than peak period elasticities. Smaller cities and less well served suburbs also exhibit higher elasticities than urban areas. This is likely because urban areas are already well served and the increased service has less value to residents than it might in less-served suburban areas (Ibid.).

3.2.3 Route restructuring

Results of bus service restructuring are not consistent. While Boston's efforts in promoting radial downtown penetration generated ridership growth, other cases focused on grid systems or hub and spoke configurations produced various results and thus made it impossible to draw strong conclusions (Ibid.).

3.2.4 Coverage changes

Increased urban coverage can be achieved through radial bus routes or city crosstown routes. Roughly three-fifths of the radial and crosstown routes tested in the Mass Transportation Demonstration Projects of the 1960s have been successful in attracting a sufficient number of riders, but specific results varied due to different local conditions. Possible configurations for changed suburban connections are radial route extensions, reverse commute routes, and suburb-to-suburb routes. A majority of these types of bus routes attracted enough patronage to be retained after experimentation periods, and the two examples in Dallas achieved very high ridership gain (Ibid.).

3.2.5 Feeder/distributor service

Cases of circulator/distributor routes differ from each other in terms of target markets and results. Both positive and negative ridership response have been seen in these cases. Feeder routes generally attract a considerable number of riders. After two or three years, new residential and multipurpose feeder services to trunk-line bus services and commuter rail typically generate 100 to 600 daily trips, and single purpose employer shuttles attract 25 to 600 daily trips (Ibid.).

3.2.6 Job Access—Reverse Commute (JARC) service

Sponsored by the Federal government, disadvantaged neighborhoods-to-jobs routes have succeeded in providing bus service to transportation-disadvantaged populations. Women and racial or ethnic minorities in numerous low-income areas tend to reap the greatest benefits from such service. JARC routes offer real social equity benefits, but tend to have low ridership (Ibid.).

3.3 Transit pricing and fares

The purposes of fare changes are increasing revenue to maintain transit operations, transit promotion and education, supporting local economies, and/or congestion reduction. Travelers' response was mainly examined by fare elasticities, ridership, and revenue. A variety of factors such as fiscal, socio-economic, and operational reasons determined traveler response in terms of fare changes. Also, different locations and conditions experienced different effects (McCollom & Pratt, 2004).

3.3.1 Travelers' response

Travelers' response to fare changes depends on conditions such as transit modes, destinations, time of travel, and fare categories. There are significant differences between buses and heavy rail transit (HRT). Because HRT is often perceived as a fast and reliable commuter mode, its fare elasticities are half of the bus fare elasticities in the same area. Similarly, peak hour ridership is less sensitive to fare changes because most of the users are workers who have limited schedule flexibility. Charging lower fares in off-peak hours increases ridership for non-work purposes such as shopping and personal business. Introducing new fare categories such as student pass programs and monthly passes also can increase ridership and/or revenue. Unlimited passes can be expected to generate more off-peak, non-commuting trips, for choice riders that might see the zero marginal cost as a compelling factor. The users who purchase an unlimited travel pass tend to travel until at least the "break even" point—the number of trips which would equal the cost of a pass at the one-way fare. Some strategies such as free fare in downtown Seattle result in loss of revenue even though the ridership increases (Ibid.).

3.3.2 Effectiveness by location

As city size increases, rider sensitivity to fare changes decreases. Cities with populations more than one million have lower fare elasticities than cities with less than 500,000 population—people in less-congested smaller cities tend to drive automobiles for convenience. In addition, the costs of vehicle ownership and parking are lower relative to transit fares in suburban areas than in urban areas—potentially increasing choice riders' sensitivity to fare changes (Ibid.).

3.3.3 Conditions and effectiveness

Large cities—such as New York—have low fare elasticities because of heavy traffic congestion, expensive parking, large populations of transit commuters, and a variety of fare categories such as monthly passes. New York experienced 6% annual ridership growth when the MTA introduced multi-use electronic transit passes. Downtown and urban areas may present similar conditions when there is a high quality of transit service, offering an opportunity to encourage a modal shift from automobile to transit. Suburban cities may also increase ridership through fare changes when they have good transit service, frequent travelers such as workers and students, and flexible fare categories. Effects, however, appear to be consistently less than in urban areas. Reducing fare levels will likely generate more ridership, but total revenues tend to decrease. Significant fare increases can also cause overall losses of revenue due to ridership decreases, so role of increasing transit fare is limited as a means of increasing revenue (Ibid.).

3.4 Park and ride

Park and ride facilities enable efficient collection of passengers via automobile, and ease the transition from low- to high-occupancy transportation. In addition, if these facilities are designed and located favorably, it is likely that they will concentrate rider demand at sufficient levels to expand transit service capabilities to low density areas. Due to this demand concentration, park and ride facilities may warrant high service quality. In addition, such facilities may provide for convenient and safe locations to meet and park for carpoolers. Finally, park and ride facilities mitigate issues of limited downtown parking and may result in improved air quality (Turnbull, Pratt, Evans, & Levinson, 2004).

3.4.1 Travelers' response

A variety of contributing factors influence traveler response to park and ride facilities. Paramount among those factors is the distance an individual needs to drive to a facility. According to *TCRP 95*, travelers tend to use park and ride facilities that are close to home relative to the whole trip. Travelers rather favor facilities that are conveniently located, highly visible, and easily accessible. Users also prefer to travel toward their eventual destination on their way to park and ride facilities, and tend to avoid backtracking. Travel time is another key factor influencing traveler response (Ibid.).

3.4.2 Conditions for maximum impact

Given that the destination point for most park and ride facilities are CBDs, facilities located in the CBD or nearby in the urban core will likely perform poorly. On the other hand, park and ride lots are the most effective with suburban park and ride facilities at least 5 miles from the destination point being served, and preferably 10 miles or more away. There is a limit, however, to how far away an effective park and ride facility can be from the CBD. If a facility is located too far out on the urban fringe, it will struggle to draw the necessary patronage to be adequately utilized. As a result, the most effective facilities are located near the midpoint between the CBD and the urban fringe (Ibid.).

Additionally, it is favorable for a facility to be located just prior to congested locations on highways, particularly if the facility is easily accessible and visible from the highway. According to user surveys, the top three features of a park and ride/pool facility are amenities, transit service levels, and the provision of a safe and comfortable atmosphere. Since most park and ride users are choice users, travel time as well as costs (including parking costs at the destination and tolls) must be competitive with their vehicle. Access time to facility, transit service frequency, and transit travel time all factor into overall travel time, and are important considerations when deciding whether park and ride facilities are used (Ibid.).

3.5 Parking pricing and fees

Parking pricing strategies to promote mode shifts to transit include baseline fee increases, short-term verses long-term fee differentials, and elimination of employer parking subsidies. Travelers respond to these strategies in different ways, with varying levels of effectiveness in terms of increased transit usage (Vaca & Kuzmyak, 2005).

3.5.1 Travelers' response

In general, for commute trips, parking demand is inelastic with price (i.e. demand, which is measured by number of cars parking, does not change substantially when the price changes). Not many data are available on elasticity of parking demand and pricing regarding non-work travel. This inelastic finding may be attributed to hidden factors in the calculations: the potential to shift parking location to a less costly location, the overall supply of parking, modification of parking duration, utilization of readily available transit, employer parking subsidies, and other incentives (rideshare, etc).

- *Fee increases/decreases:* If no other commute options available, an across-the-board parking surcharge will not yield much change in demand or mode for commute trips.

- *Peak period surcharges:* Surcharges can decrease peak accumulation in commuter lots by at times 50%. Rather than switching modes, however, travelers will usually modify their choice of parking facility, modify their parking duration, or modify their entrance/exit time according to the optimal rates (i.e. wait until 10:00AM to arrive at work).

- *Increase in rates per duration:* Commuters choosing the SOV mode decreased both in significant numbers and percentages when rates are heavily increased for long-term stays. A Chicago study found a 50% decrease in the number of 3-24 hour commuters when long term-public parking prices increased to be on-par with near-by privately owned downtown ramps. The authors of the study suggested that the 50% fewer commuters using public ramps switched their travel mode from SOV to transit.

- *Elimination of employer parking subsidy:* In 18 case studies of employment sites, the share of SOV decreased by 21 percentage points when employer subsidies were removed. However, this shift did not directly relate to gains in transit share. If HOV incentives are offered, it was found that SOV users shifted to carpooling over transit.

Typically, commuters respond to parking fees by shifting from the personal vehicle to utilizing other means of transportation, typically either transit or carpooling depending on availability of transit (Ibid.).

3.5.2 Conditions for maximum impact

Parking fees are most effective at modifying travel mode when parking options are limited. Indeed, the presence of alternative parking options will decrease how effective parking fees are. On a related note, parking fees, if not applied universally to all parking options, instead of causing a shift in travel mode, may cause a shift in travel destination. This may relocate the economic opportunity represented by the trips themselves, leading to economic dislocation. Parking fees are most effective when proper site design is utilized and there are options for other travel modes. Parking fees are not effective when travelers have no option other than to drive due to lack of pedestrian sidewalks, bicycle storage facilities, or a proper transit system connected to their destinations. However, when transit options are readily available, parking fees are found to be one of the most effective tools at reducing SOV trips.

The effectiveness of parking fees is heavily dependent on where the commuter starts and the effectiveness of transit between the starting point and the work location. If the traveler starts in a heavily urban area where there is an active, above average transit system, then the decrease in SOV trips due to increased parking costs will be reflected in increased transit usage. If the traveler starts in a suburban area where transit service is poor or below average, then parking fees will not result in a shift towards transit, but will instead result in either increased revenue generation from parking or increased HOV mode share. The effectiveness of parking fees is also heavily dependent on the socio-economic status of commuters. Commuters in the lower quintile population are eight times more likely to make changes in their trip mode from SOV to transit in response to parking fees than commuters in the highest quintile. The explanation for this phenomenon is two-fold. One, the high quintile commuters prefer faster trips due to the life-value that “time is money”. Two, the parking cost is a larger percentage of daily income for a low-income earner than it is for a high-income earner. That percentage difference can be outside the expendable income of low-income commuters, forcing a mode shift in order to stay within their transportation budget (Ibid.).

3.6 Parking management and supply

Parking management refers broadly to strategies such as minimum/maximum parking requirements, employer/institutional parking management, on street commercial area parking management, peripheral parking, park-and-ride lots which are all designed to influence traveler decisions through pricing, supply and demand discrepancies, increased total travel time and, direct subsidy (J. R. Kuzmyak, Weinberger, Pratt, & Levinson, 2003).

3.6.1 Minimum/maximum parking standards

The most direct option to manage parking supply is through direct minimum and maximum parking requirements. Historically, municipalities use minimum parking requirements to ensure ample supplies of parking and to minimize competition for street parking, as well as the amount of walking from vehicle to destination. This policy resulted in an oversupply of parking in most situations (few developers therefore chose to develop beyond the standards) and thereby undermined motorists’ ability to competitively recognize the full cost of transportation modes which encouraged an automotive centric culture, accelerating the sprawl movement (engraining this strategy in many rural and exurbs). Attempts to a shift away from the policy has been difficult and unsuccessful in rural areas and proven near impossible in historically auto centric suburban neighborhoods. When cities have attempted to implement maximum parking requirements that varied greatly from the previous minimums, developers fought back, claiming their properties would be uncompetitive (Ibid.). Today, however, this pattern may be changing somewhat—at least in urban areas: a 2012 study of Twin Cities developers found minimum parking requirements may actually hinder development in transit-friendly urban neighborhoods by needlessly increasing costs (Fan & Guthrie, 2013).

3.6.2 Area-wide restrictions

In urban areas (mainly central business districts) some cities have established statutory limits on parking expansions throughout an entire area. When area-wide regulations have been implemented less than half of workers continued to drive alone to work, at least at peak times, shifting travelers to combinations of peripheral parking, park-and-ride lots and transit. Alternative or complementary area-wide parking management encourages employers/institutions to implement their own private parking management programs. Policymakers can either require this through the area-wide parking management or through minimum/maximum parking requirements—ideally, the private entity chooses to do this on their own. Private parking management programs vary greatly based on their administration and can be very effective in any setting if properly tailored to the traveler’s needs. In Albany, NY the State of New York created a shuttle system to encourage state employees to utilize peripheral parking lots and in Little Rock Arkansas a facility merged a carpool priority program with a restrictive maximum parking policy to nearly triple the number of carpoolers (Ibid.).

3.6.3 On-street parking

On-street commercial area parking allows municipalities to dictate parking situations ranging from installation of meters, to duration limits, to requirement of parking permits. Primarily these strategies are necessary in urban areas with high populations on the outskirts of the core as well as heavily utilized suburban business districts. These strategies are mainly intended to prevent people from undermining other strategies (Ibid.).

3.6.4 Peripheral parking

As automotive travelers are forced out of the central business district by different policies and programs one typically sees peripheral parking (located anywhere from a few blocks to a few miles out of the CBD) demand increase. Travelers find this peripheral parking very attractive because of its typically lower prices than options in the central business district while remaining just a short distance from their final destination. Depending on the distance, since the travelers must continue to travel beyond the peripheral parking location we see differing methods of transportation for the final leg varying from walking, carpooling, private shuttle, and transit. It is important to note the difference between peripheral parking and park-and-ride, peripheral parking is typically in an urban environment relatively close to the final destination while park-and-ride is typically closer to the origination point and serves as a rallying point for travelers to converge and proceed with the majority of their trip on a highly concentrated method of transit versus single occupancy vehicles (Ibid.).

3.7 Road Pricing and HOT Lanes

Road value pricing is the act of charging users for roadway use during congested periods. The idealized implementation would charge road users based on their marginal cost imposed upon other users. The technique most relevant is to price individual lanes, typically taking the form of High Occupancy Toll (HOT) lanes. The toll is set dynamically to ensure vehicles on the HOT lanes travel at approximately free-flow speeds. This strategy offers the easy creation of transit advantages—routes for buses to travel with little to no impacts from congestion—without requiring a dedicated guideway (J. Evans, Bhatt, & Turnbull, 2003).

3.7.1 Travelers' response

Road value pricing generally prompts increased transit use due to the increased cost of driving alone. Increases in transit use are contingent, however, upon the presence of sufficient transit service serving trips made by drivers impacted by value pricing. This includes cases where new lanes were added to an existing corridor in the form of HOT lanes. Despite this increased capacity which could incentivize driving as congestion decreases (and tolls replace transit as a means to ensure a more consistent travel time) no decrease in transit ridership was found, and it instead increased in all but one studied case (Ibid.).

3.7.2 Conditions for maximum impact

Transit needs to be an efficient and convenient substitute for driving alone in order to convince users to switch mode. Additionally the greater the difference in cost (in both time and money) between transit and driving the more likely people are to utilize transit. Transit is a cost-effective alternative when it is unaffected by congestion—such as HOT lanes, dedicated right-of-way, bus on shoulder etc.—as this increases the cost disparity between transit and driving. Transit can be further aided by road pricing when revenues are used (at least in part) to subsidize transit (Ibid.).

3.8 Land use and site design

Land use planning and site design are closely related sets of tools to control the development within communities. Including zoning, regulatory controls for growth/development, building codes, and Transit Oriented Development, these tools can potentially reduce vehicle miles traveled, increase transit's mode share and efficiency, and increase the pedestrian use of activity centers. The impacts of land use and design are broken into three categories: density, diversity, and design (J. R. Kuzmyak, Pratt, Douglas, & Spielberg, 2003).

3.8.1 Density

Density is related to the number of dwellings/residents, job opportunities, or services available. Overall population density is one important factor in determining the success of transit; denser populations are more supportive of transit than lower densities simply due to more potential users in proximity to the line. Moreover, higher population density brings with it, in many cases, a higher density of services, jobs, and activities which make transit service more useful for accessing a larger variety of destinations.

With various destinations in dense areas, a wide spectrum of transit service can be deployed to adequately serve demand and maintain high levels of service. High quality transit within dense areas will then further incentivize itself against driving. This sets up a virtuous circle as strong transit options are bolstered by the demand they pull away from driving. Furthermore, dense regions have higher competition for limited auto space, both for trips and parking, further helping to push people toward transit. Nationwide, residential density near heavy and light rail stations had an effect on increased ridership, with lesser effects for commuter rail. In one study, transit modes became more important in areas with more than 10,000 persons per square mile, with only 22% auto and taxi ride mode share in areas with more than 50,000 persons per square mile. Additionally, a study of high-density inner and low-density outer ring suburbs in Chicago showed that the inner ring suburbs used commuter rail at twice the proportion of the outer ring suburb due to their proximity to more transit options (Ibid.).

3.8.2 Diversity

The jobs/housing ratio is one diversity index used to indicate the availability of employment relative to the population within a region. Although in many cases employees do not live in extremely close proximity to their workplace, a balanced jobs/housing ratio indicates that a region does not need to either import many workers to fill jobs or export workers to other regions. In Florida, a good balance of housing and jobs increased the transit mode share by two percentage points over na area with homogenous land use. A study of a suburban area noted that in a suburban employment center a 1% increase in commercial/retail space was correlated to a 3% growth of transit and ridesharing.

Accessibility is also partly determined by land use diversity. Higher accessibility is dependent not only on mixed development but also the availability of high quality transit services. Well developed, mixed use areas will have strong ridership which allows for differentiated transit service which further promotes accessibility (Ibid.).

3.8.3 Design

The particulars of development, such as integration for bicycles and pedestrians, transit friendliness, layout of infrastructure, plays a role in determining the success of transit. In urban environments, centralizing such destinations may be a strong positive enhancer for transit mode share. The actual impact depends on a variety of localized factors. In general, however, planning for site design that accounts for transit use and in some way disincentivizes private vehicles will tend to help transit mode share (Ibid.).

3.8.4 Conditions for maximum impact

The above outlined strategies are most successful when used in tandem with one another. Increased density makes the other strategies much more effective. Increased density brings the market for increasing transit service, and therefore an interest in investing in land use mixing as well as more attention to design than in a less dense area. Less dense suburban areas generally showed lower transit ridership because there likely was not enough density to make a public investment in transit (Ibid.).

3.9 Transit-oriented development

Transit oriented development (TOD) can generally be considered “moderate to high-density development, designed with pedestrian priority, located within an easy walk of a major transit stop” (J. Evans, Pratt, Stryker, & Kuzmyak, 2007). Objectives of TOD include more opportunities to meet work and non-work travel needs through walking and transit, attraction of choice transit riders, and creation of interesting places near transit stations, among other priorities.

3.9.1 Travelers' response

The response of travelers to TOD depends on where a TOD is located within a metro area (urban or suburban context) and the transit mode (heavy rail, commuter rail, LRT, BRT, or local bus). The transit component of TOD is of critical importance to the success of any TOD project. Providing high quality transit service within the context of a TOD site will have significant benefits to transit ridership. In turn, high-quality transit will enhance the value of developing near a transit station. TOD projects that create high density, diverse land uses and transit and pedestrian oriented design tend to generate high transit mode share and high walking access share.

Parking management and highway access affect TOD effectiveness. Transit tends to benefit from limited and costly parking, inconvenient highway access, and severe congestion. These factors represent conditions both within and beyond the control of a single TOD site. While parking can be managed at a site it cannot be controlled at a destination. Similarly, a TOD site can be located away from convenient highway access, but it cannot control congestion on a highway. It is thus important to recognize the context of a TOD site is also significant in the overall success of that site (Ibid.).

3.9.2 Conditions for maximum impact

Studies show that urban TOD projects tend to have the highest transit mode share for both work and non-work trips, and the highest proportion of transit users accessing transit stations on foot. Suburban TOD projects are often held up for their potential to create change in travel behavior, but research shows that these projects are less likely to be effective than urban TOD projects. Urban TOD projects also produce very large increases in transit mode share by introducing housing and non-daytime uses into typically office-dominated areas. LRT-oriented residential conversions in downtown Denver reportedly increased transit mode share from 20% - 35%.

Scholarship on suburban TOD projects shows that mode share for commuting to work is relatively high for work trips, but much lower for non-work trips. The reason is that residential TOD projects in these areas are still relatively auto-dependent. These TODs are usually located on one spoke of a radial transit network that only goes in one direction. This makes it difficult for residents of these TODs to reach non-work amenities that are located in multiple directions. For example, a study in Portland, OR showed that non-work mode share was 4 times higher for central city TOD areas than for suburban TOD areas. On the other hand, suburban Portland TODs still had 170-190% higher transit mode share than non-TOD areas. Portland's results are more encouraging than elsewhere. A California study showed that suburban TOD projects were not consistent in achieving higher transit mode shares, and some of the projects actually had lower mode shares than traditional suburban areas (Ibid.).

The type of transit system also influences the impact TOD has on mode share. Studies show that heavy rail TODs (such as those in Arlington, VA and California) consistently produce dramatic increases in transit mode share, whereas mode share increases associated with commuter rail and LRT are more context-dependent. For example, LRT-oriented TODs in the suburban San Francisco bay area produced more modest and sometimes indiscernible positive impacts on both work and non-work mode shares whereas LRT-oriented TOD in urban and suburban Portland were more encouraging. One explanation is that transit supportive land uses and constrained parking in urban Portland supported mode shifts to transit. Commuter rail TODs included predominately residential development and generally produced high mode shares for commute trips, but not for non-work trips. Studies of BRT and local-bus TODs were more limited. One study showed high mode share for BRT oriented development in Ottawa, Canada and another showed successful implementation of local bus oriented TOD in Boulder, CO and King County, WA. The King County project included affordable housing options attractive to transit dependent residents (Ibid.).

3.10 Pedestrian and bicycle facilities

Offering easy connections to stations for pedestrians and cyclists can increase transit ridership significantly and cost-effectively. Transit agencies need to access modes, which generally involve walking for the final few blocks of travel. Ensuring these connections will grow the effectiveness of transit (Pratt et al., 2012).

3.10.1 Walking distances

Overall, for every hundred feet a development moves from a transit station, approximately five fewer individuals per hundred dwellings use transit in a typical day. Creating a system of non-motorized infrastructure to reduce walking distances would greatly benefit transit, effectively expanding its coverage.

The quality of transit service is critical in determining the walk-shed that a station will produce. Bus service is often cited as having a quarter-mile walk-shed, which covers 90% of the riders on buses. Rail is cited as a half-mile walk-shed; in suburban neighborhoods this is comparable to bus ridership, while in urban neighborhoods a half-mile walk-shed covers approximately 50% of the riders who access the line on foot. Planning pedestrian facilities based on actual walking distances (*network distance*) helps build a more realistic picture of coverage than planning based on airline distances. Research suggests that in areas of full coverage 8% of all commuting is done by transit, where even half coverage has difficulty reaching 4% mode share by transit (Ibid.).

3.10.2 Mobility-limited riders

High-quality non-motorized transportation infrastructure also allows riders with mobility limitations to use fixed-route transit services, reducing the need for high-cost paratransit services. This benefits all system users: mobility-limited users gain schedule flexibility, and paratransit services compete less with fixed-route services for often scarce operating funds (Ibid.).

3.10.3 Bicycle accommodations

For cyclists the accommodation of bicycles by transit agencies—on vehicles and at stations—is very important. Bike lockers and secure locking stations can increase the combined transit and bike mode share by as much as 40%. On board facilities for bicycles can have even greater benefits: where bicycles are allowed on board transit vehicle, nearly three of every four people who access the system riding bicycles bring them aboard. To attract all but the most dedicated cyclists, a transit provider must ensure that access to stations is well-maintained and safe. Bike lanes are three times as important as bike locker style facilities at stations for infrequent and casual users of the transit system, who tend to be more concerned with traffic safety than security for their machines. Increasing comfort as well as security could lead to large increases in bicycle ridership to access transit (Ibid.).

3.10.4 Examples

In Chicago's Metra commuter rail system, park and rides are the primary way passengers access the system. Improved pedestrian and bicycle connectivity increased non-motorized access mode shares by 7%, and most of these riders said they had previously driven alone to stations. The improvements allowed for increased ridership growth or decreased maintenance on park and ride facilities, as spots were opened from a higher proportion of patrons accessing the station by walking. In the city of Chicago results become less clear, as pedestrian improvements did not reduce automotive access, but did reduce use of bus connections to access the L. People who already had decent to good access to transit chose to bypass transfers and directly use their feet to access the main mode of their transportation.

High rates of bicycle access to transit can dramatically increase a transit station's catchment area, as bicycles allow riders to travel further, faster and often with greater ease than walking. In the San Francisco Bay Area, the Cal Train commuter rail service has taken advantage of this fact to significantly increase reverse commute ridership, by way of Silicon Valley tech workers brings their bicycles with them to hasten their trip to the office once off the station. The extra range afforded by bicycles means that approximately 7% of Cal Train's rides involve bicycles on vehicles (Ibid.).

3.11 Employer and institutional TDM strategies

Like any good or service, transportation has a supply and a demand. Transportation Demand Management (TDM) refers to the practice of managing and reducing demand through incentives and disincentives to meet supply; this is contrary to supply side strategies that augment supply to meet demand. There are a variety of strategies that can be used in TDM programs with different levels of traveler response and different locations call for different strategies (J. Kuzmyak, Evans, & Pratt, 2010).

3.11.1 Employer/institutional support actions

Employer or institutional support actions are strategies that reduce the use of single occupancy vehicles during peak hours by providing transportation coordinators who offer trip planning and assistance to employees to increase transit and connect carpoolers. On-Site Transit Information and Pass Sales remove barriers that may prevent some from riding transit; they provides information on routes, pass sales, and how to board and request stops. Preferential parking sets asides premium parking spaces, either close to the entrance or covered, for carpool or vanpools to further encouraging high-occupancy vehicles. Finally, secure bike storage, lockers, and changing facilities can encourage additional bicycle use.

This is the most basic approach to TDM, and often is the least effective. These programs are most effective where transit service is high, like urban areas. To increase the impact of TDM, employer support actions should be heavily marketed and coupled with other programs. The TCRP evaluated one case study in New York State showing the "Transportation Days" promotional event helped shift single occupancy vehicle rates among attendees from 68.6% to 63.7% (Ibid.).

3.11.2 Provision of transportation services

Employers may also directly provide alternative transportation arrangements. These arrangements may include shuttle bus services, privately contracted transit service, vanpool formation, company vehicles and bicycle loan programs. Each of these methods provides more choice than a single-occupancy vehicle.

Providing transportation services directly is very effective in reducing vehicle trips in places where existing public transit is difficult to access. When these methods involve providing modal subsidies and employer provided transportation services, vehicle trips may be reduced by almost 27% (Ibid.).

3.11.3 Financial incentives/disincentives

Financial incentives or disincentives provide an actual monetary benefit (or cost) to alter travel demand for single-occupancy vehicles. Companies can work with local transit agencies to provide low- or no- cost transit passes, which are untaxed by the Federal government up to $230 per month. Additionally, charging for parking increases the cost for driving and may reduce vehicle trips.

Financial incentives have proven to be very effective in reducing vehicle trips. Transit subsidies, on average, reduce vehicle trips by 21%, carpool subsidies reduce vehicle trips by 23%, and parking discounts for high-occupancy vehicles reduced vehicle trips by 26%. TCRP found that when parking was restricted, fees levied on existing parking, and subsidies for carpooling, the vehicle trips were reduced by 30% (Ibid.).

3.11.4 Summary

TDM programs are most effective when businesses and institutions are located near transit. When high transit accessibility is paired with transit subsidies, the vehicle trip reduction is 27.4%. But this doesn’t mean that businesses and institutions with medium or low transit service can’t offer effective TDM programs, their focus may just need to change from transit use to high occupancy vehicle (such as vanpool, carpool).

Chapter 4: Review of Ridership Modeling Techniques

Predicting the likely ridership impacts of transit-use promotion strategies is crucial to determining what specific mixes of strategies are most appropriate under specific circumstances. As a rule, transitway planning prominently includes ridership predictions as a means of demonstrating demand, evaluating cost-effectiveness and in fulfillment of explicit Federal funding requirements. These predictions are generally made using traditional, four-step regional travel demand models. Four step models are quite effective for predicting the impacts of regional highway improvements—their original intended purpose (Pas, 1995). Such models, however, have serious shortcomings with regard to predicting the impacts of transit use promotion strategies. First, four step models ignore important predictors of transit use, such as walkability, employment density and land use mix. Second, four-step models use a large geographic unit of analysis—the Transportation Analysis Zone or TAZ. TAZ's are designed to (and do) allow for effective modeling at the regional level; however, transit use promotion strategies are frequently applied at much smaller geographic levels—such as the station area. As a result, TAZ's may offer too little geographic precision. Finally, four-step models ignore the micro-scale built forms of trip origins and destinations in predicting mode choice, even though local built forms are known to have significant impacts on transit use rates, particularly among choice riders (Cervero, 2006a).

As an alternative to four-step models, direct ridership models are increasingly recommended by the literature for the flexibility they offer planners in specifying determinants of ridership. (Cervero, 2006a; Gutierrez, Cardozo, & Garcia-Palomares, 2011; Kuby, Barranda, & Upchurch, 2004). Direct ridership models use multiple regression analysis to predict proposed transitway ridership (dependent variable) based on a set of ridership predictors (explanatory variables). A direct ridership model can incorporate any measurable factor that influences transit use (Cervero, 2006; Kuby et al., 2004). A review of the existing literature, however, shows that little research explores the potential of direct ridership modeling to inform the implementation of transit supportive policies *in addition to* transitway implementation.

Post-processing—another possible refinement in transit modeling—refers to methods for adjusting model results to account for effects not easily considered in the model itself using elasticities (Cervero, 2006a). Examples of post processing include adjustments to regional travel demand models in San Luis Obispo, CA and Atlanta, GA to account for local density, land use mix and urban design attributes not considered at the regional scale (Fehr & Peers, 2005; Walters, Ewing, & Schroeer, 2000). Post-processing is suited to deriving mode shift from ridership as it allows consideration of elastic phenomena, like bus-transitway mode shifts and car shedding among non-transit-dependent households (Ewing, 1998), while allowing for ridership modeling based on widely available public data and well-established methods (Kuby et al., 2004).

The station-level ridership model portion of this research employs direct ridership modeling to predict transitway ridership based not only on service levels, economic and urban form characteristics, but also on transit-*related* policies such as those discussed earlier in this literature review, including zoning, parking requirements/pricing, employer-provided commute benefit programs and provision of bicycle and pedestrian infrastructure. The station-level ridership model further refines those predictions by deriving auto-transit mode shift predictions through the use of established post-processing techniques, albeit for a novel purpose.

Chapter 5: Case studies

5.1 Chicago

The Chicago region grew from a tiny lake port to a great city on the world stage almost entirely in the original transit era. One of a handful of North American Cities to never abandon rail transit, Chicago has continually, if gradually, improved its iconic “L” rapid transit system as well as the commuter railroads and bus services that connect with it. In addition, Chicago has also adopted a number of service delivery improvements common among much more recent “new start” systems, and is taking an increasing interest in leveraging its strong transit system to guide development along transit-supportive lines.

5.1.1 Service improvements

The Chicago Transit Authority (CTA), which operates the L and urban bus routes, built its last new rail line in 1993—the 13-mile Orange Line, connecting the downtown Chicago Loop with Midway Airport. The results were impressive: within a year of opening, average weekday boardings had reached 37,500, and overall transit ridership in the corridor had grown by 31%, while commute mode share grew from 16.4% to 21.5%. In addition, over 25% of riders self-identified as new to transit, demonstrating a significant mode shift even very soon after implementation (LaBelle & Stuart, 1995). Service improvements implemented since have consisted largely of new routes on existing trackage, in some cases necessitating the addition of new connections between lines. This process began with the 1993 creation of the Red and Green Lines, by swapping the southern braches of the old West-South and North-South routes (Young, 1998). The 2006 Pink Line combines a former Blue Line branch with new service over a former non-revenue track segment to create a new line able to serve additional destinations and offer higher service frequencies (Chicago Transit Authority, 2006). CTA has also undertaken a multi-year track rehabilitation program aimed at eliminating slow orders and returning the entire system to a state of good repair (Chicago Transit Authority, 2013c)(Chicago Transit Authority, 2013b). In addition, the northwestern Brown Line recently benefitted from a significant capacity expansion to reduce excessive load factors stemming from ridership growth (Chicago Transit Authority, 2009), and the Green, Pink and Yellow Lines have seen long-gone stations rebuilt, expanding service areas without actual line extensions (Chicago Transit Authority, 2010; Chicago Transit Authority, 2012). Extensions are currently proposed for the Red, Yellow and Orange Lines, and planning is underway for two BRT corridors as well (Chicago Transit Authority, 2013b).

5.1.2 Service delivery improvements

The Chicago region has also implemented a number of service delivery improvements common to newer systems and aimed at regional system integration, as well as legibility. In the early 1990’s, CTA introduced color-coded lines throughout the L system, replacing historic destination-based line names. This change dramatically eases wayfinding for prospective riders who are new to transit (Young, 1998). Chicago’s three regional transit providers, CTA, the METRA commuter rail system and the PACE suburban bus system also offer a variety of discounted regional pass options (Chicago Regional Transportation Authority, 2013). In 2013, CTA and PACE launched the innovative Ventra touchless, smart-card fare system, allowing for full fare integration between the L and both urban and suburban bus routes. Ventra cards double as prepaid debit cards; in addition, riders will soon be able to link their existing touchless bank cards to a Ventra account or use them to pay one-way fares without creating accounts at all (Chicago Transit Authority, 2013a).

5.1.3 Catalyzing development

Unlike many regions with new start rail systems, the Chicago region's formative period of growth occurred at the height of the original transit era. Also, despite mid-Twentieth Century contractions, high-quality regional transit service has always been a defining feature of Chicago. As a result, much of the Chicago region's built form is already inherently transit-oriented: leveraging the transit system to produce sustainable growth patterns is not primarily a problem of retrofitting transit orientation to an inherently auto-oriented form, but rather one of enhancing an existing transit-oriented form (Mouw et al., 2010). CTA and the City of Chicago use the term "Transit Friendly Development" (TFD) to describe this concept, defined specifically as "Development which is oriented towards and integrated with adjacent transit. The development incorporates accessibility and connectivity and is a multiuse mix of dense development that generates significant levels of transit riders" (Ibid.). Special emphasis is placed on pedestrian connectivity within and through developments, as Chicago sees TFD as augmenting the transit demand of surrounding neighborhoods with significant baseline demand. CTA and the City of Chicago have developed a TFD Station Area Typology, which classifies all 144 L stations into seven types of places, including:

- Downtown core,
- Major activity center,
- Local activity center,
- Dense urban neighborhood,
- Urban neighborhood,
- Service employment district, and
- Manufacturing employment district.

These typologies categorize stations according to appropriate densities, scales and mixes of uses and activities. By articulating a desired role for each station area to play in the city's urban fabric, the typology offers a ready-made starting point for TFD planning in station areas (Mouw et al., 2010).

Transit-oriented (or –friendly) development in Chicago has received less attention from the literature than TOD efforts in new start cities, such as Portland, OR or San Diego, CA. To some extent, this lack of study may stem from the simple fact that TOD is not particularly remarkable in a city like Chicago, even if it is not often self-conscious of being TOD. Hess and Lombardi find this to be a common state of affairs in large cities with well-established, legacy transit systems. In their words: "Unlike the Sunbelt cities, which saw the majority of their growth occur during automobile-dominated times, development along transit corridors is so customary in older cities that they rarely call it TOD; it's simply regular development"(Hess & Lombardi, 2004).

5.1.4 Results

Transit use is clearly growing in Chicago: over the period from 1996 to 2011 (the earliest and latest years available from the National Transit Database), total unlinked passenger trips grew 17%, from roughly 545 million to nearly 638 million. Growth came mostly from CTA L services and Metra commuter rail services, with modest growth in CTA bus services and more or less stable ridership on PACE suburban buses (National Transit Database, 1998; National Transit Database, 2013). Transit's commute mode share grew modestly (though from a large base for a Midwestern city) between 2000 and 2011—increasing from 25% to 27% in the City of Chicago, and from 12% to 13% in the entire urban area (United States Census Bureau, 2013).

5.2 Ottawa

Canada's capital city, like Chicago, is a sprawling metropolis in the Great Lakes region, with few geographic limits to its outward growth. Also like Chicago, it is a clear transit success story. The similarities, however, largely end there. With the exception of a compact downtown core, Ottawa's metropolitan growth occurred largely in the automobile era, resulting in low densities and automobile-oriented residential areas, reminiscent of the U.S. Sunbelt. Ottawa also does not have a legacy rail transit system, having abandoned all streetcar services decades ago.

5.2.1 Transit system development

Soon after its creation in 1969, the Regional Municipality of Ottawa-Carleton (RMOC—Ottawa's regional planning body) formulated a vision for regional growth of a multicentric region, but with a strong downtown and relatively concentrated employment and commercial subcenters. The RMOC's original 1974 Regional Development Strategy called for concentrating growth into high-capacity transportation corridors. This general statement of principal eventually evolved into the Transitway—a dedicated, grade-separated busway, provided with online stations and its own entrance and exit ramps. From the late nineteen-eighties to the present, this system proved singularly well-suited to the region's built form, and to the RMOC's goals for regional development. In addition to providing a rail-like service on the Transitway itself, Ottawa took full advantage of the inherent route flexibility offered by a bus-based system, by forming a system of transitway routes with "local tails" where buses begin their runs with local pickup in residential areas before entering the Transitway for the trip downtown. This system orgainization allows Ottawa to offer high quality service to low-density residential areas without undue dependence on park and ride facilities. This in turn allows the development of more intense (and more truly transit-oriented) nodes of development at outlying Transitway stations (Cervero, 1998).

Not surprisingly, Ottawa is often held up as a poster child for BRT systems. Today however, the region is transitioning to a hybrid rail/bus system. In 2001, OC Transpo (Ottawa's transit provider) opened the O-Train—a diesel-powered light commuter rail service connecting Carleton University and surrounding residential areas to two branches of the Transitway using existing freight track (OC Transpo, 2013). Despite not serving downtown and capacity constraints imposed by single track operation, the O-Train's ridership has grown to 14,300 average weekday boardings (American Public Transportation Association, 2013)(National Transit Database, 2013), serving as something of a proof of concept for rail in the region. In addition, Ottawa's vaunted busway is in danger of becoming a victim of its own success. The route on city streets taken by Transitway buses through downtown Ottawa is becoming increasingly congested, despite the provision of exclusive bus lanes. Limited by road space and the need to accommodate local bus routes as well to 180 buses per hour per direction, the Transitway has reached capacity in BRT form. A significant further increase in transit use to central destinations, however, is a major planning goal of the RMOC. As a result, in the Summer of 2013, OC Transpo began construction to convert the main trunk-line section of the Transitway from BRT to electric LRT, and to replace downtown street operations with a tunnel. Dubbed the Confederation Line, this project will dramatically expand Transitway capacity, and free up both street space and equipment for improved local bus service when it opens in 2018 (James, 2008; Metropolitan Knowledge International, 2010).

5.2.2 Channeling development

The Ottawa region has also benefitted from decades of transit-focused regional development planning. Starting with the original Regional Development Strategy of 1974, the RMOC identified rapid transit station areas as the desired foci of regional employment and commercial growth. In addition, while Ottawa's regional planning called for significant growth in suburban centers, it was also careful to keep those centers subordinate to downtown. Regional planners have also used the RMOC's veto power over local plans, as well as subdivision regulations to encourage transit-supportive development around Transitway stations. In addition, the RMOC and OC Transpo have prepared a set of transit-supportive development guidelines, which call for mixed uses at secondary employment centers to reduce employees' need to drive for lunch or errands during the work day. These guidelines also require developers to collaborate with transit planners in forming development concepts; this requirement helps ensure pedestrian and bicycle connectivity to stations and the placement of the most intense uses closes to stations. OC Transpo and the City of Ottawa have also deliberately reduced parking both in downtown Ottawa and in Transitway station areas; the city allows automatic reductions of parking requirements at transit-served destinations (Cervero, 1998).

Development impacts have been significant: from 1986 to 1991 (soon implementation of the first Transitway section), Transitway station areas accommodated 35% of all regional job growth. Stations designated as primary employment centers have also become magnets for regional commercial development, ensuring a variety of activities and skill levels of employment in station areas. In terms of residential development, however, the flexibility of Ottawa's BRT system has proven to be a double-edged sword: by allowing OC Transpo to route Transitway buses into lower density areas on regular streets, before collecting them together onto the Transitway itself, BRT has served to reinforce low-density residential development patterns. Though transit serves commute trips and trips to regional shopping centers quite well, this development pattern increases automobile dependence for other trip purposes (Cervero, 1998).

5.2.3 Results

In terms of ridership the results of Ottawa's unique transit system are impressive. Currently, fully 23% of motorized trips within the city of Ottawa are taken by transit. As of 2006, roughly 22% of all commute trips (including non-motorized modes) in the RMOC were by transit. As of 2011, weekday ridership on the transitway had reached 244,000, with 543,000 boardings for the entire system (American Public Transportation Association, 2012). It must be noted that Ottawa is a relatively high-income region (higher than either Toronto or the province as a whole) in a nation with high rates of automobile ownership—as such, it appears quite likely that Ottawa's transit system attracts a significant number of trips which would otherwise be driven. In addition, by reinforcing the strength of downtown and the regional centers in station areas—and by making it possible for both to be denser than would be feasible with heavier reliance on the automobile—OC Transpo has allowed the planning and realization of a built form that creates less need to travel at all.

5.3 Discussion

Chicago and Ottawa have both found a mix of transit-use promotion strategies that fit their own circumstances and have both met with considerable success. Despite their clear differences, several commonalities appear between the two regions:

- *High-quality transit service* The Chicago and Ottawa transit systems take very different forms, but both provide fast travel times by virtue of exclusive rights-of-way and grade separation where appropriate, and both offer a high-quality rider experience.

- *Regional scope* Chicago and Ottawa both plan for and provide transit on a regional scale. Transit may take differing forms in different parts of the two regions, but both share a commitment to transit as a basic, region-wide service.

- *Strong centers* Chicago and Ottawa are both strongly-centered regions, with traditional downtowns as their dominant centers of employment and commerce. Ottawa proves that having additional regional centers does not prohibit high levels of transit use, but strong centers are a critical component of both regions' success, especially given sprawling residential suburbs.

- *Continuous improvement* Whether it is Chicago' creation of entire new L routes by stringing together existing track in new ways or Ottawa's willingness to tear out the key section of its celebrated BRT system to build LRT, both regions demonstrate a commitment to continuously improving their transit systems.

- *Regional integration* Ottawa's BRT system (and timed transfers with local routes) provides a near seamless rider experience throughout the region. Chicago has further to go along such lines, but the implementation of the Ventra fare system shows an important commitment to serving complex, regional trip patterns as conveniently as possible.

- *Transit as focus for growth* Both regions also, through various means, have regional growth patterns focused on station areas. In Ottawa, this focus was arrived at through several decades of careful regional patterns. In Chicago, growth never wholly turned away from transit station areas, and recent planning initiatives—such as the Transit Friendly Development Guidelines—now deliberately reinforce that pattern.

With Chicago beginning BRT implementation as a supplement to its rail system and Ottawa building light rail, both regions also seem to be becoming part of a broadly emerging pattern of first class transit systems including both rail and premium bus service. Above all, they demonstrate the value high-quality transit brings to widely varying urban regions.

Chapter 6: Mode Choice Model Data and Variables

The data used for this study come from three main sources. All of the data were provided by the Metropolitan Council. The first is a one-day travel diary, a component of the 2010 Travel Behavior Inventory (TBI) administered by the Metropolitan Council. The second is skim data administered by Cambridge Systematics, Inc. The skim data contain travel times, monetary costs, and other travel-related information between any two transportation analysis zones (TAZs). The data from these two sources were combined to create the final full data set. In particular both trip data and skim data are identified by the codes of TAZ origin and TAZ destination. By using these codes to match the data sets, we created a unified data set.

The third data measure land use variables of TAZs. Since land use data are only available in the seven-county metropolitan area (Twin Cities), the boundary of land use variables was limited to the metropolitan area. That is, although the Twin Cities and collar counties include 3000 TAZs, the land use data contain variables for TAZ 1 through 2485. So we created a second data set, which has land use variables in addition to trip and skim data, but is limited to observations within TAZ 1 through 2485.

The original travel diary data have none different mode choices including driving, transit, non-motorized modes, and others. Because the purpose of this study is to examine the competition between personal vehicle and transit, we consider only the following four modes: Drive Alone (DA), Shared Ride (SR, car-pooling), Transit Drive (TD, park and ride) and Transit Walk (TW, walk access to transit). If the primary mode of a trip is Bicycle, Walk, School Bus, Taxi or Other, it was deleted from the data set. This brings the number of trips down from 79236 to 70876 (or 10.6% of the initial number of observations). If any of the remaining observations contain Bus, Light Rail or Commuter Rail, it was regrouped under Transit. Because Light Rail and Commuter Rail have much smaller shares than Bus, we cannot further distinguish transitway trips from regular bus trips. Of these observations regrouped under Transit, if one of the other two modes contains automobile, the observation is classified as Transit Drive. The remaining is classified as Transit Walk. The rest of the observations are all auto-related trips. They are split into Drive Alone or Shared Ride based on the autotype variable that distinguishes the number of individuals in the car (Drive alone, without passengers). In the data for the Twin Cities and collar counties, 2.2% of trips include transit. The data for the Twin Cities have a similar transit share (Table 1).

Table 6.1: Mode Share in the Two Data Sets

	Twin Cities and collar counties		**Twin Cities**	
	N	Percentage	N	Percentage
Drive alone	41549	58.6	36194	59.2
Shared ride	27754	39.1	23601	38.6
Transit drive	212	0.3	156	0.25
Transit walk	1361	1.9	1174	1.9

The key independent variables include the characteristics of trips, the characteristics of trip makers, and land use variables (Koppelman and Bhat 2006). First, individuals' mode choice for a particular trip depends on its travel time and travel cost by different modes. Travel time for a transit trip includes in-vehicle travel time, access time, and wait time. In-vehicle time is the time spent in actual transit. Access time is the time spent getting to transit stop. Wait time is the time spent at transit stop. The literature suggests that people perceive different times differently. So when we develop the mode choice model, we have attempted to produce the coefficients for the different times. Since travel time is a cost, it should be negatively associated with mode choice. However, when we include all three travel times altogether, some coefficients became positive. This is inconsistent with the travel behavior theory. As a result, we adopted the weights in Transit Capacity and Quality of Service Manual (TCRP 2003) to compute a composite travel time. In particular, travel time = in-vehicle travel time + 2.2 * access time + 2.1* wait time.

Travel cost is a sum of gas cost and transit fare. Gas cost is the cost spent on gas so it only applies to alternatives that involve auto: Drive Alone, Shared Ride and Transit Drive. For Transit Walk, this value will be 0. This variable is calculated by pulling the distance-driven data and then multiplied by $0.15. We further distinguish the gas cost for Drive Alone and Shared Ride. Participating in a Shared Ride mode allows individuals to share the cost so we divide the gas cost by the number of individuals on the trip for the Shared Ride gas cost. However, the number of individuals is not always available; sometimes individuals did not report the data or a different mode was chosen so that no data exist. For these unique situations, we substituted in the average number of individuals on all Shared Ride observations (1.51). Since transit fare is a transit variable, there will only be values for the Transit Drive and Transit Walk alternatives. For Drive Alone and Shared Ride, this value will be 0. For the observations with missing data, we use the same substitution technique as with the gas cost by taking the average of fare from existing data.

Second, mode choice is associated with the purpose of the trip. For example, people are more likely to take transit for commute trips than non-work trips (Pucher and Renee 2003). We have identified four key trip purposes, including home-based work (HBW), home-based other (HBO), non-home-based work (NHB), and non-home-based other (NHO). The classification is based on trip destination and origin.

Third, mode choice is affected by land use characteristics of both origin and destination (Ewing and Cervero 2001). We developed two population density variables: one is for trip origin and the other is for trip destination. Again, the density variables are limited to TAZs in the Twin Cities.

Finally, mode choice varies by demographic characteristics of trip makers. Demographics include age, gender, household income, number of workers and number of cars in the household. The demographic data come from the TBI.

Chapter 7: Mode Choice Model Methodology

The data for the Twin Cities and collar counties have 70,876 observations with each observation representing a specific trip by a single individual. Each individual could be part of multiple trips and each household could have multiple individuals within the data set. An important part of our model is that we are using a variable choice data set. This means that although there are four mode choices for each observation, some observations may not have any skim data available for certain transit alternatives. For example, transit was not available between certain TAZ areas. For observations where a certain alternative is not available, we simply removed that alternative from the data set. This also means that for a number of observations, we may not have data for the mode choice indicated from the travel diary. These observations then needed to be removed and the final data set ended up with 70,639 observations while the data with the density variables ended up with 61,125 observations.

The final model form we chose for our analysis is the multinomial logistic regression model (MNL). The MNL model requires the outcome variable to be nominal. It predicts the probability of selecting each alternative as a portion of the utility of all the alternatives combined (Koppelman and Bhat 2006). The expression for the probability of choosing a specific alternative x from our four alternatives (DA, SR, TD, TW) is

$$\Pr(x) = \frac{Exp(V_{x)}}{Exp(V_{DA}+V_{SR}+V_{TD}+V_{TW})}, \tag{1}$$

where V represents a utility function of each alternative (Figure 1c).

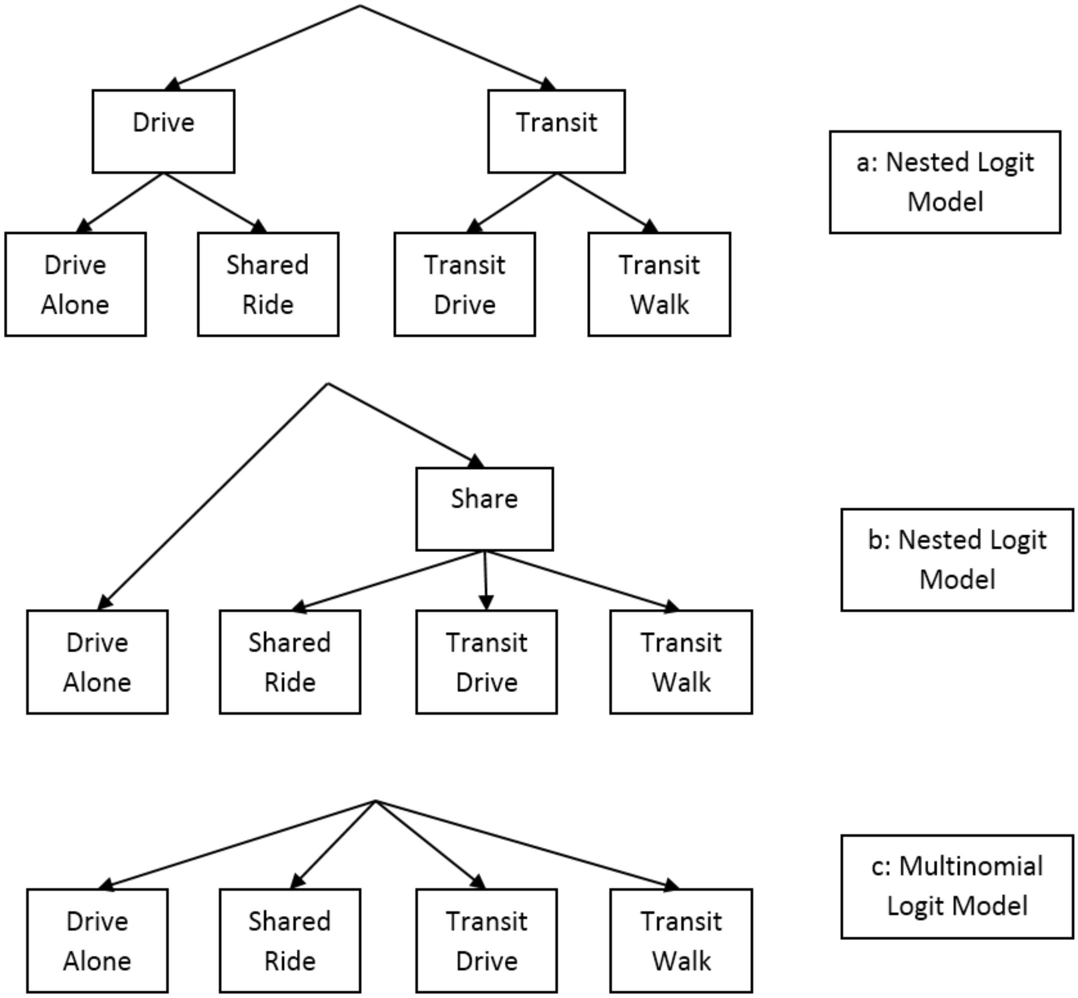


Figure 7.1: Mode Choice Model Structures

A similar model that we first attempted to develop was the nested logistic regression model (Figure 7.1a and 7.1b). This model differs slightly from the MNL model. The MNL model assumes the Independence of Irrelevant Alternatives (IIA) property. This property basically states that all mode choices compete equally with each other. However, it may not always be true in every situation. The nested logistic model corrects for this issue by grouping certain alternatives together. We attempted various types of nests by grouping the car and transit choices together (Drive Alone with Shared Ride and Transit Drive with Transit Walk, see Figure 7.1a), single occupant and multiple occupant choices together (Drive Alone and Shared Ride with Transit Drive with Transit Walk, see Figure 7.1b), auto and walk choices together (Drive Alone with Shared Ride with Transit Drive and Transit Walk), and so on. However, all of these various nests produced IV parameters significantly larger than 1, rejecting the nested logistic model (Koppelman and Bhat 2006). Thus, after all of the attempts, we decided to choose the MNL model.

Another aspect of our analysis is to assess the elasticity of key independent variables. The elasticity measures the percent change in dependent variable (in this case, the probability of choosing a particular mode) if an independent variable increases by 1%. For the data in the Twin

Cities and collar counties, we looked at the elasticity of travel time and travel cost. For the data in the Twin Cities we looked at the elasticity of origin population density and destination population density. For each variable we also looked at the cross-elasticity. For example, if transit travel time increases by 1%, what is the percent change in the probability of choosing Drive Alone? The formulas used for these calculations are:

$$\text{Elasticity(j)} = \left(1 - P_j\right) * \beta_x * X, \qquad (2)$$

$$\text{Cross-elasticity(j)} = -P_j * \beta_x * X, \qquad (3)$$

where P_j is the probability of choosing mode choice j, β_x is the coefficient of variable x, and X indicates the level of variable X (Koppelman and Bhat 2006).

Since the elasticity depends on the level of variable X, we wanted to examine how different levels of variable X change the elasticity (see Figure 7.2). We did this by pulling various percentiles from the data for each of the four variables in question. For travel time and travel cost, this involved calculating one hundred percentile values for each. However, rather than just looking at each variable individually, we wanted to see how travel time and travel cost interacted together. This meant calculating the elasticity of all combinations of travel time and travel cost together, resulting in 10,000 total elasticity calculations. For travel time and travel cost, we needed to calculate percentiles for each of the different alternatives since travel time and travel cost vary among the alternatives. The population densities are the same among all alternatives.

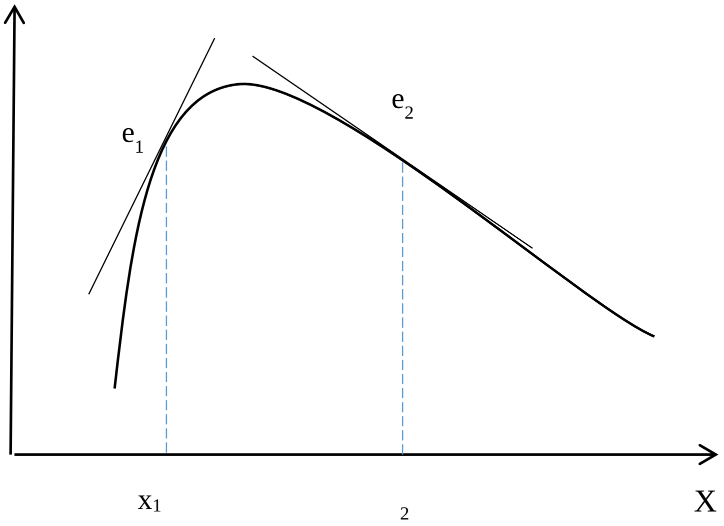


Figure 7.2: Varying Elasticities by the Level of X

Chapter 8: Mode Choice Model Results

Table 8.1 illustrates the MNL model for the data in the Twin Cities and collar counties. Travel time, travel cost, and the number of transfers are alternative specific variables. In other words, they vary by the four modes of transport. Other variables are constant across different modes. The reference category is Transit Walk. That is, the interpretation of the coefficients is relative to the mode of Transit Walk. The market-share-based McFadden R-square is 0.194, which is within its typical range.

Travel time, travel cost, and the number of transfers are negatively associated with mode choice. These are reasonable because they are generalized travel costs and carry disutility. The monetary cost of in-vehicle travel time is equivalent to $17.55 per hour (=60*0.012/0.041). Similarly, the transfer penalty is equivalent to $10.18 per transfer or about 35 minutes of in-vehicle travel time.

In terms of demographic variables, we found that affluent people are more likely to choose Shared Ride than Transit Walk; women are more likely to choose Shared Ride and Transit Drive than Transit Walk; seniors tend to choose Drive Alone more than Transit Walk. The number of workers is negatively associated with Shared Ride, presumably because their employment locations are not in the same direction or area. As expected, the number of cars has positive associations with all auto-related modes.

Table 8.1: Mode Choice Model for the Twin Cities and Collar Counties

Variables	Drive Alone	Shared Ride	Transit Drive
Constant	-2.820	-1.012	-5.903
Travel time	-0.012	-0.012	-0.012
Travel cost	-0.041	-0.041	-0.041
# transfers	-0.418	-0.418	-0.418
Income	0.002$^{\#}$	0.002*	0.002$^{\#}$
Female	0.091$^{\#}$	0.116	0.320
Age	0.033	-0.003$^{\#}$	0.0003$^{\#}$
# workers	-0.024$^{\#}$	-0.151	0.210$^{\#}$
# cars	1.480	1.441	1.252
Home-based work	-1.049	-3.645	0.466
Non-home-based work	-0.118$^{\#}$	-1.775	0.296$^{\#}$
Non-home-based other	0.226	0.511	-1.120*
N	70369		
Log-Likelihood at constant	-53773		
Log-Likelihood at convergence	-43333		
McFadden R-square	0.194		

Notes: The reference category is Transit Walk. # the coefficient is insignificant at the 0.10 level. * the coefficient is significant at the 0.10 level. All other coefficients are significant at the 0.05 level.

For trip purposes, home-based work is negatively associated with Drive Alone and Share Ride but positively associated with Transit Drive. The implication is that Transit Drive is more popular than Transit Walk for home-based commute trips and that transit modes are more attractive than Drive Alone and Shared Ride. Non-home-based other trip shows entirely opposite patterns to home-based work trip. Therefore, transit is more likely to serve commuters. Non-home-based work is less likely to choose Shared Ride than Transit Walk. This makes sense because it is not easy to find carpoolers at a non-home location. The results indicate that individuals are more likely to use transit for any trips involving work. This is most likely related to the higher likelihood of transit options being available at work sites than sites visited for personal trips.

Table 8.2: Mode Choice Model for the Twin Cities

Variables	Drive Alone	Shared Ride	Transit Drive
Constant	-2.271	-0.393	-6.052
Origin population density	-52.1	-61.9	51.6#
Destination population density	-76.6	-90.6	16.7#
Travel time	-0.010	-0.010	-0.010
# transfers	-0.454	-0.454	-0.454
Income	0.002#	0.002#	0.002#
Female	0.106*	0.104	0.318
Age	0.032	-0.003#	0.001#
# workers	-0.015#	-0.136	0.206#
# cars	1.428	1.398	1.282
Home-based work	-1.075	-3.692	0.434*
Non-home-based work	-0.185*	-1.835	0.294#
Non-home-based other	0.178*	0.433	-1.133*
N	61125		
Log-Likelihood at constant	-46998		
Log-Likelihood at convergence	-37876		
McFadden R-square	0.194		

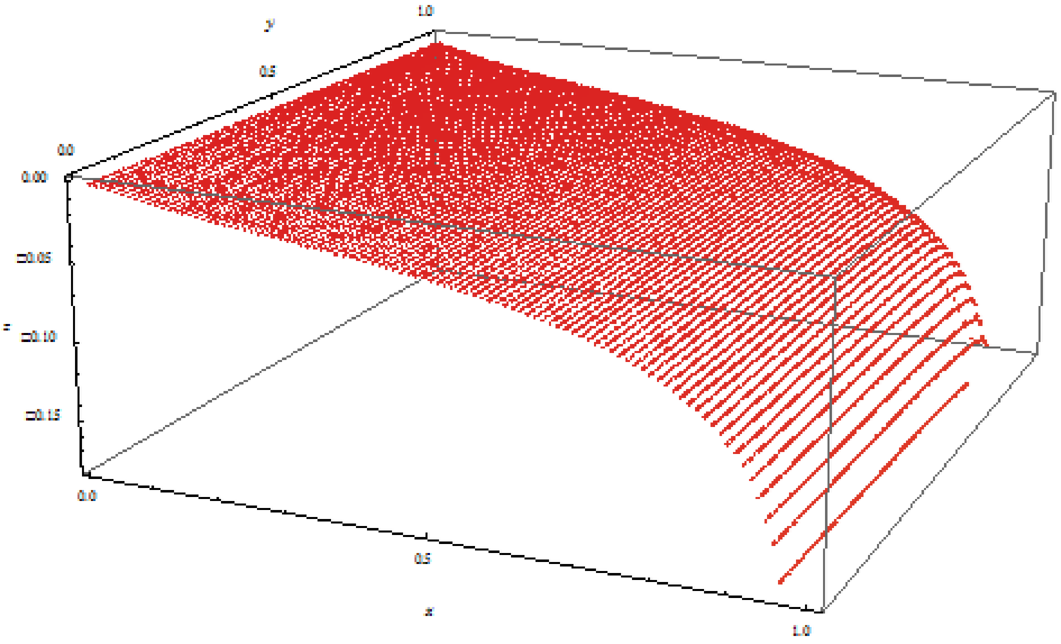
Notes: The reference category is Transit Walk. # the coefficient is insignificant at the 0.10 level. * the coefficient is significant at the 0.10 level. All other coefficients are significant at the 0.05 level.

Table 8.2 shows the MNL model for the data in the Twin Cities only. The R-square is also 0.194. Population density measures at trip origin and destination are significant for all three modes. In general, when density is high, people are less likely to choose Drive Alone and Shared Ride than Transit Walk. It seems that destination density has a more important impact on the choice of automobiles than origin density, particularly for Shared Ride. This is reasonable because it is easier to find a carpooler when destination density is high. On the other hand, density is insignificant for Transit Drive at the 0.10 level. Therefore, density matters to the choice of automobile vs. transit but it does not have an impact on how to access transit. The coefficients for all other variables are similar to those in the previous model. The inclusion of population density variables makes the travel cost variable insignificant.

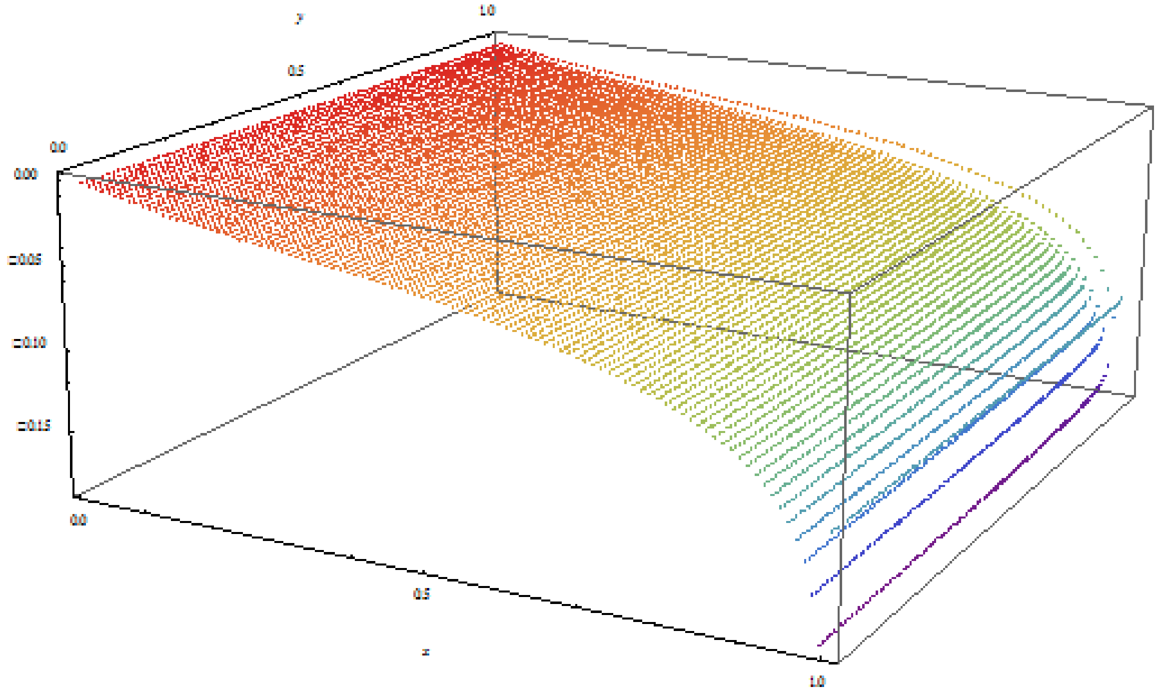
Based on the model in Table 8.1, we computed the elasticity and cross-elasticity of travel time and travel cost. Figure 8.1 shows the elasticities of travel time with varying travel time and travel cost.

As travel time increases, the elasticity for Drive Alone grows (Figure 3a). Its negative sign indicates that when travel time increases, the probability of choosing Drive Alone decreases. Therefore, reducing travel time is effective when travel time is large. As shown in Equation (2), the impact of travel cost is captured by P_j. Because the coefficient for travel cost is small, its impact on P_j is trivial relative to the value of travel time. Therefore, the elasticity slightly varies by travel cost as shown in Figure 8.1a. Figure 8.1b and 8.1c illustrate the elasticities of travel time for Share Ride and Transit Drive, respectively. The two figures follow the same pattern as Figure 1a. A comparison of the three figures indicates that travel time improvements have a larger impact on transit than driving. In particular, the largest elasticity for driving is at the magnitude of 0.15 whereas that for transit is at the size of 1.0.

Figure 8.2 shows the elasticity of travel cost. They have similar patterns as Figure 8.1. However, the impact of travel cost is much smaller than that of travel time, particularly for transit mode. Figure 8.3 and 8.4 show the cross-elasticity of travel time and travel cost. Cross-elasticity of an attribute measures the percent change in the probability of choosing one mode (say Drive Alone) when the attribute of the other mode (say Transit Drive) changes by 1%. The largest cross-elasticity of travel time for driving is about 0.3 whereas that for transit is about 2. In contrast, the cross-elasticity of travel cost is at the scale of 0.1. Overall, to improve the mode share of transit, changing travel time of either transit or driving is more important than changing travel cost. Transit is more sensitive to travel time than driving.

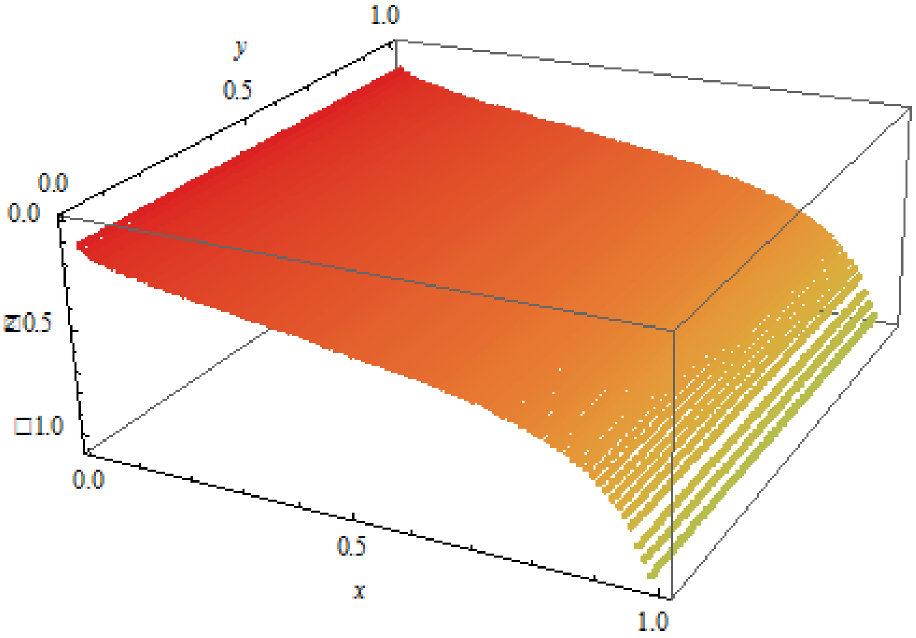


(a) Drive Alone: x = travel time, y = travel cost, z = elasticity

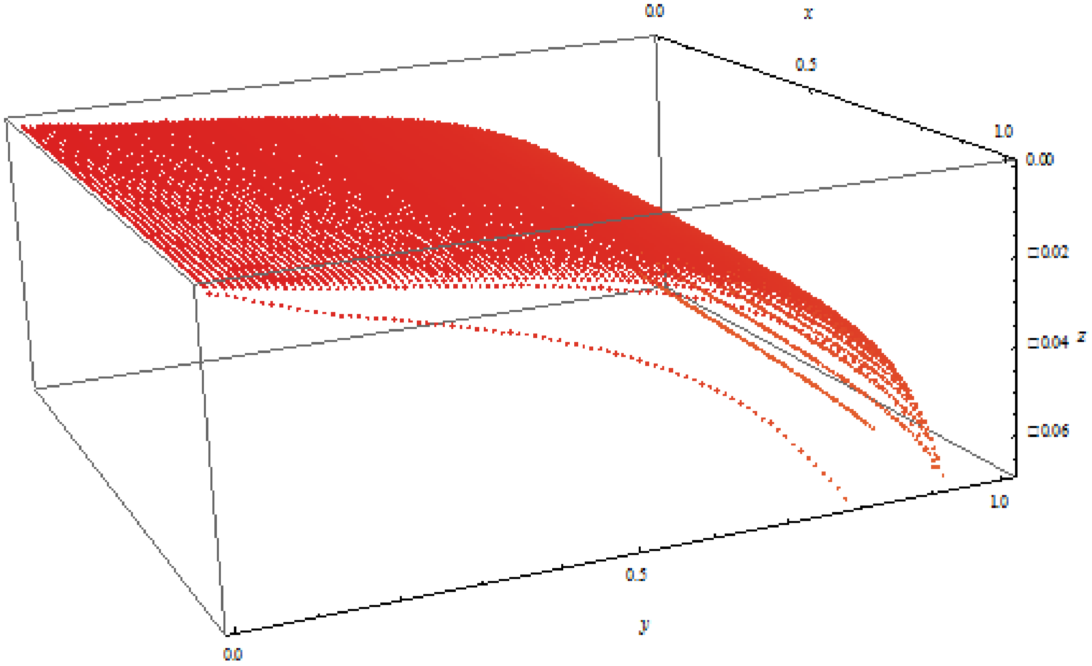


(b) Shared Ride: x = travel time, y = travel cost, z = elasticity

Figure 8.1: Elasticity of Travel Time

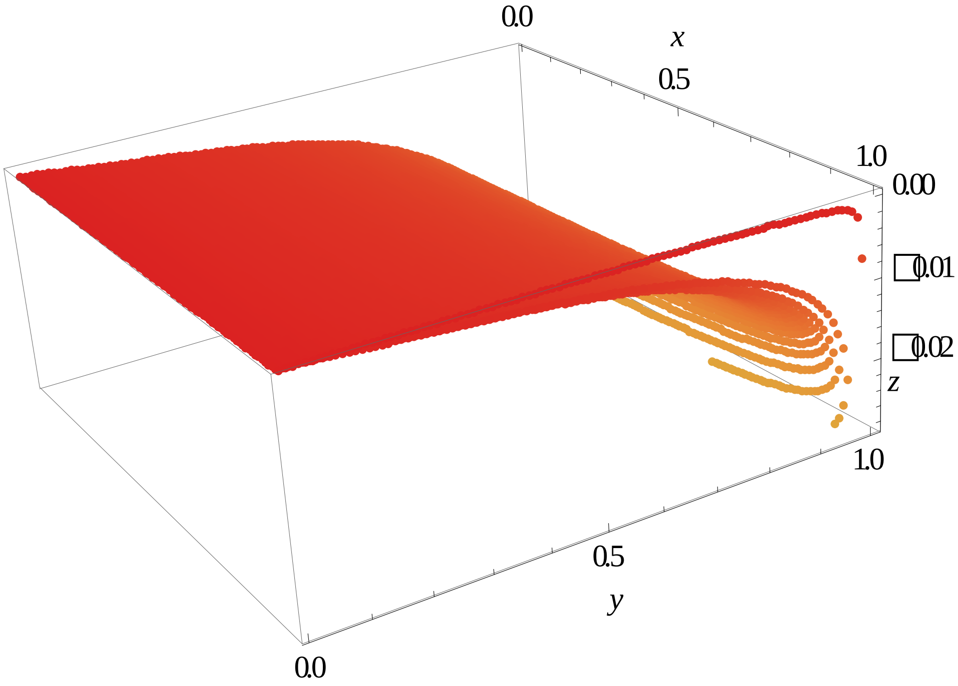


(a) Transit Drive: x = travel time, y = travel cost, z = elasticity



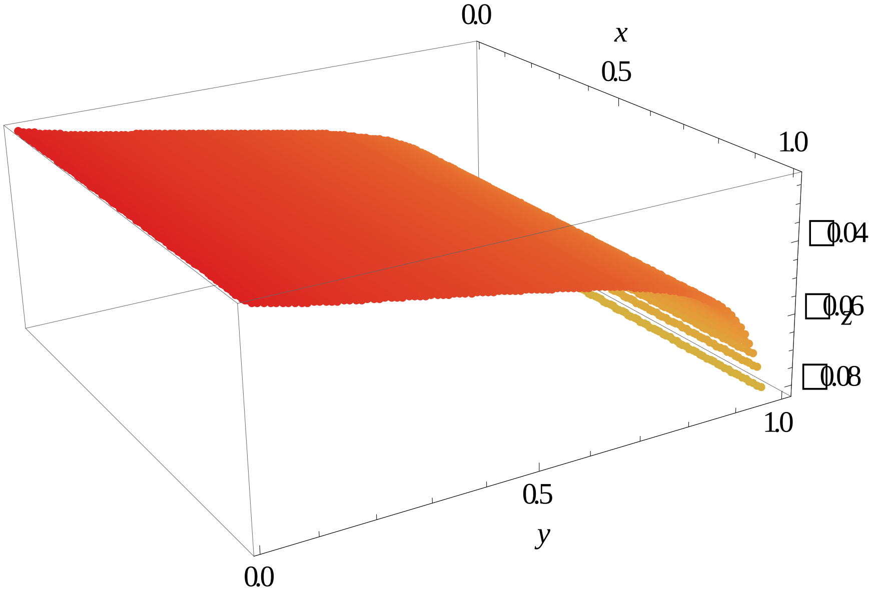
(b) Drive Alone: x = travel time, y = travel cost, z = elasticity

Figure 8.2: Elasticity of Travel Time



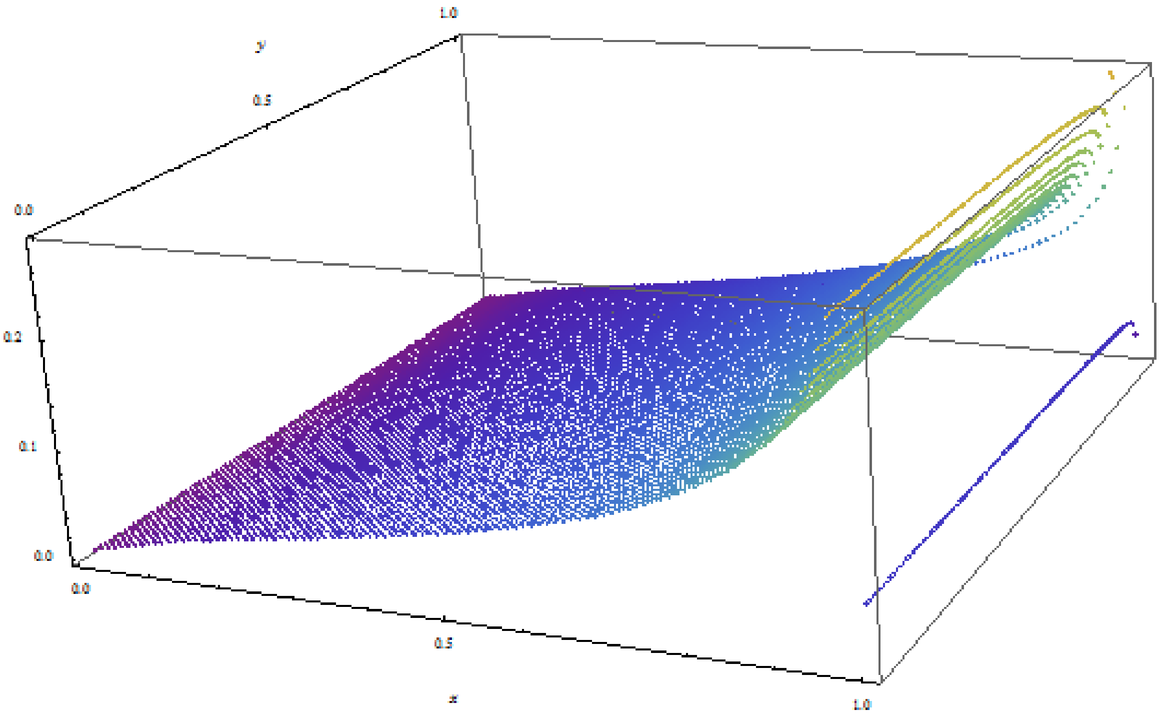
(a) Shared Ride: x = travel time, y = travel cost, z = elasticity

Figure 8.3: Elasticity of Travel Cost

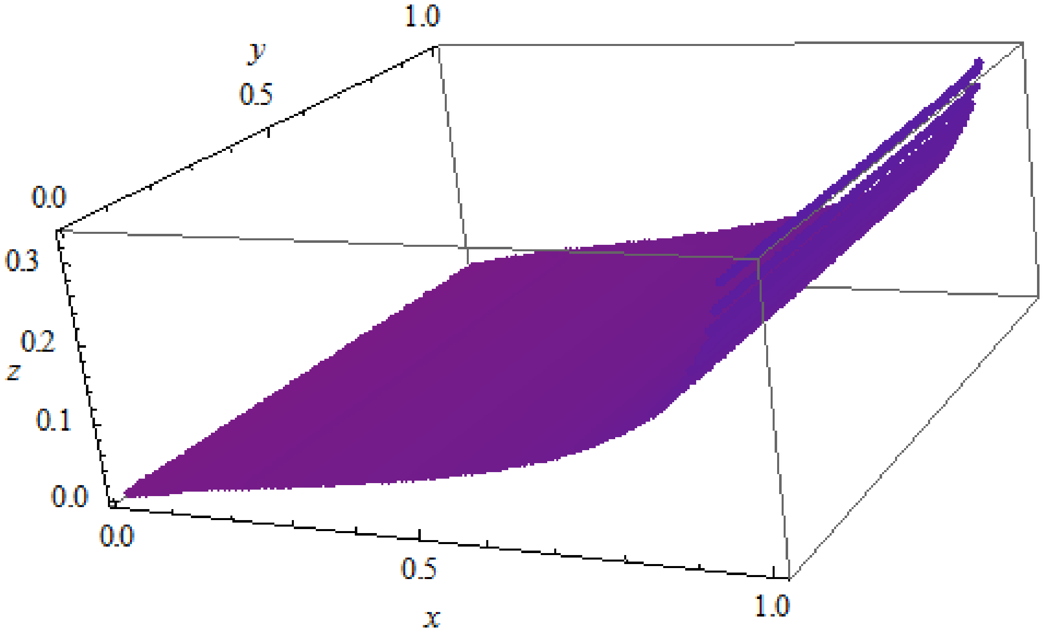


(b) Transit Drive: x = travel time, y = travel cost, z = elasticity

Figure 8.4: Elasticity of Travel Cost

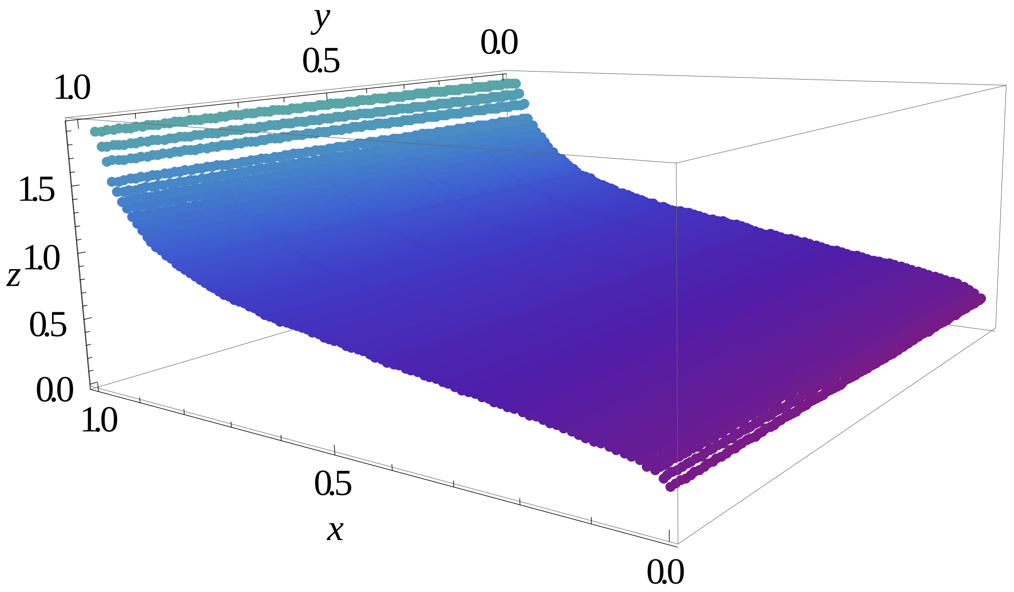


(a) Drive Alone: x = travel time, y = travel cost, z = elasticity

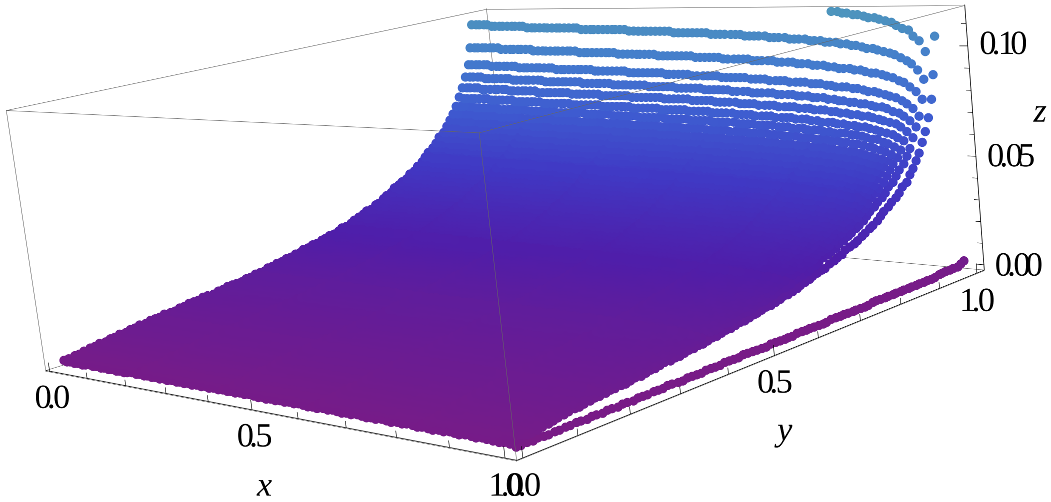


(b) Shared Ride: x = travel time, y = travel cost, z = elasticity

Figure 8.5: Cross-Elasticity of Travel Time

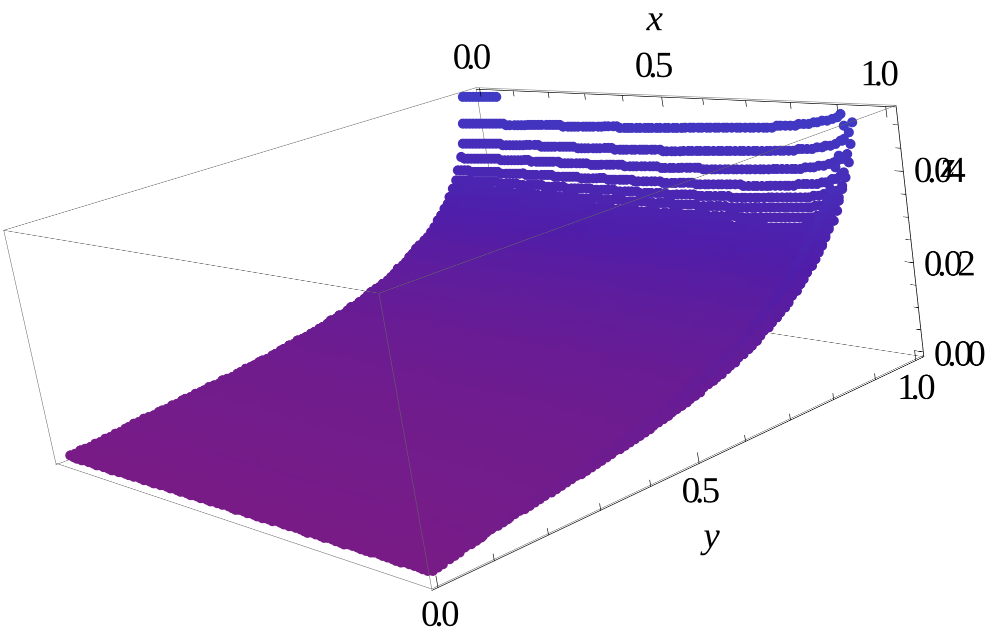


(a) Transit Drive: x = travel time, y = travel cost, z = elasticity



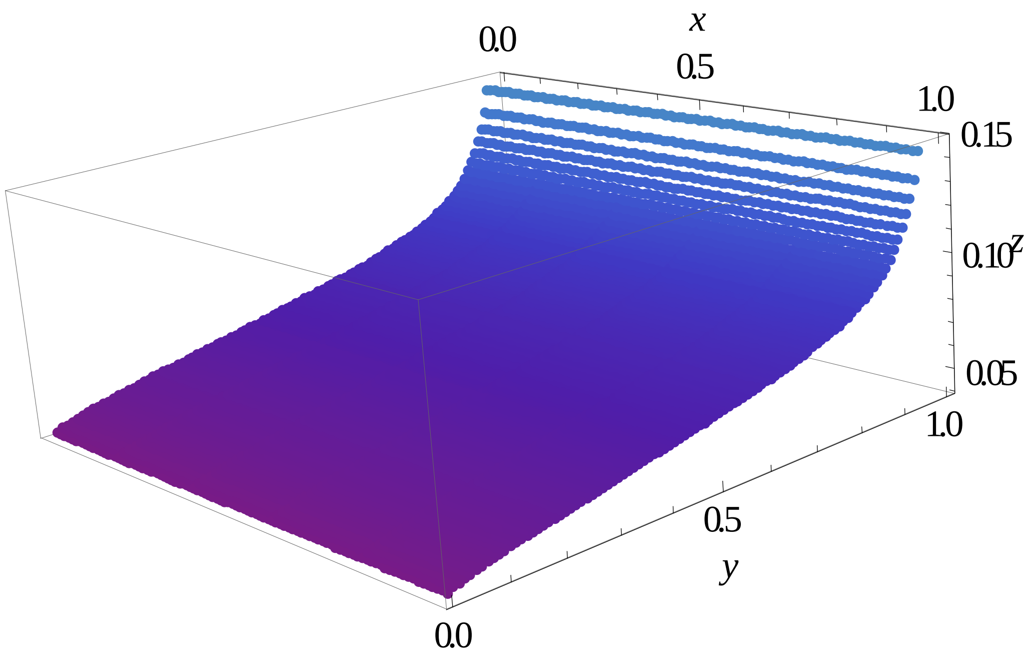
(b) Drive Alone: x = travel time, y = travel cost, z = elasticity

Figure 8.6: Cross-Elasticity of Travel Time



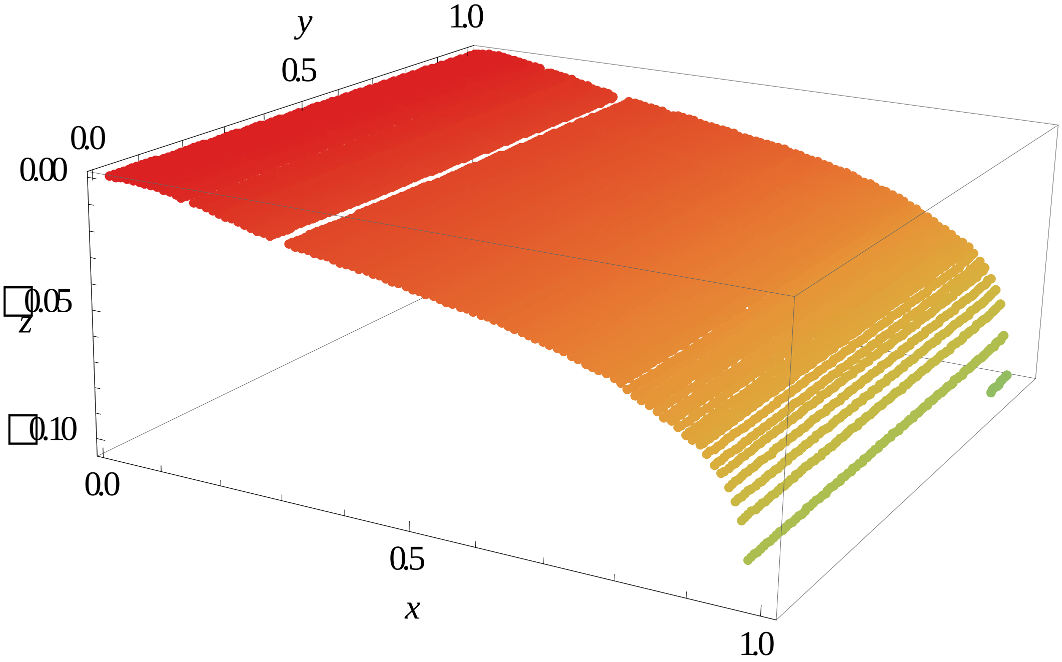
(a) Shared Ride: x = travel time, y = travel cost, z = elasticity

Figure 8.7: Cross-Elasticity of Travel Cost

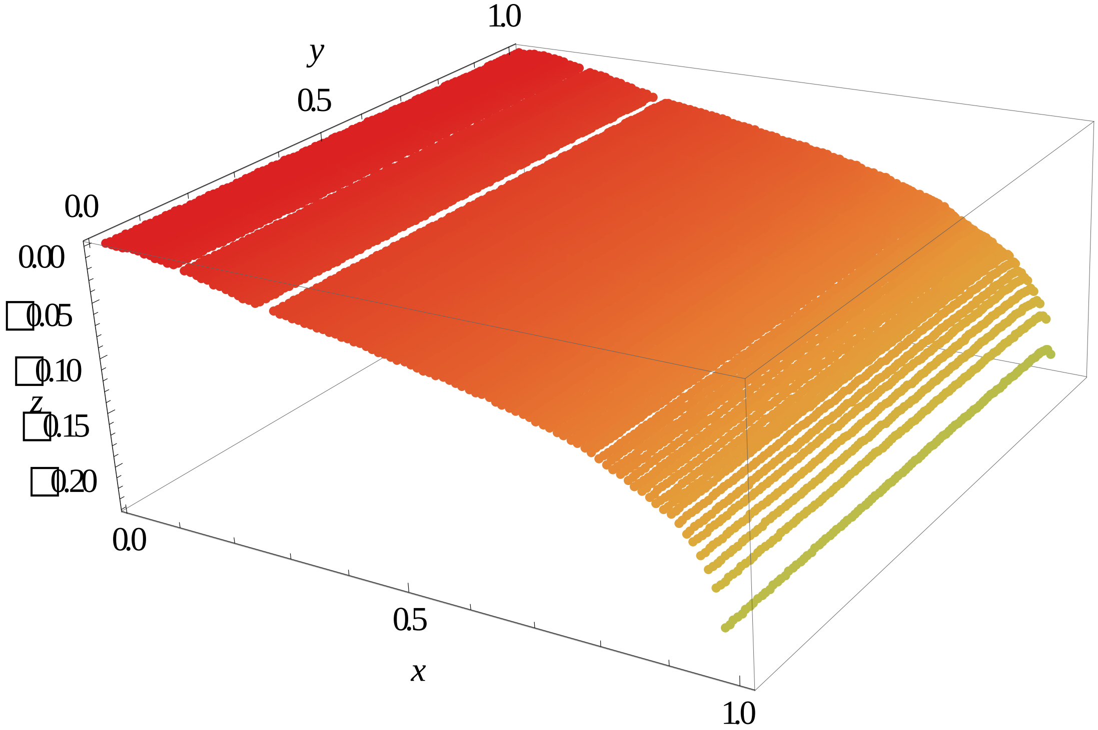


(b) Transit Drive: x = travel time, y = travel cost, z = elasticity

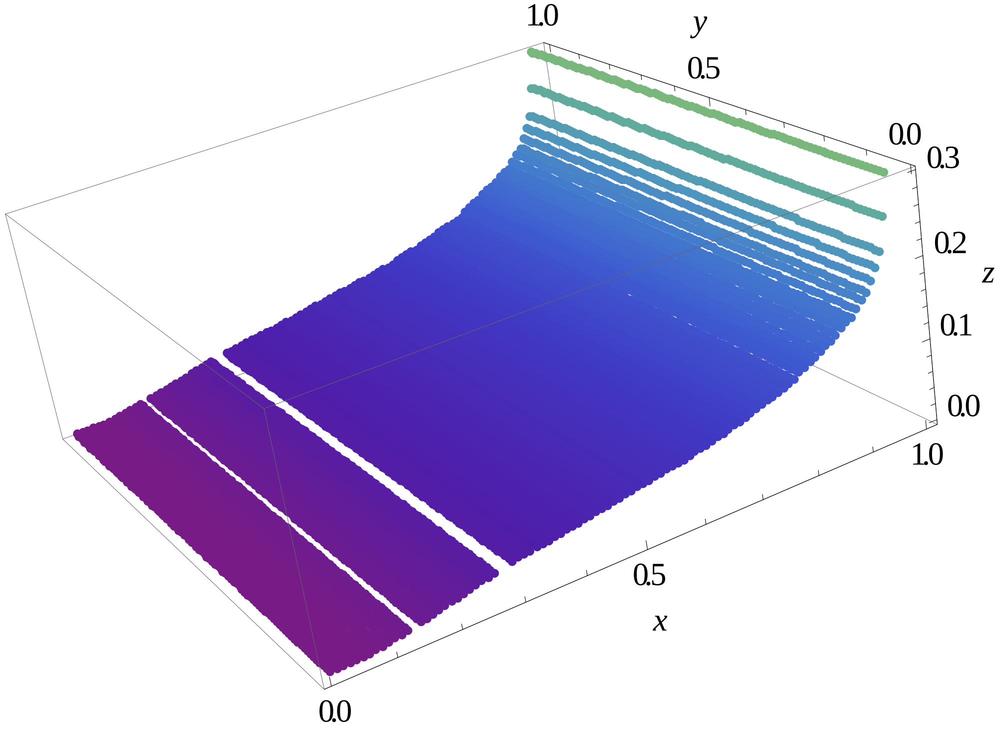
Figure 8.8: Cross-Elasticity of Travel Cost



(a) Drive Alone: x = origin density, y = destination density, z = elasticity

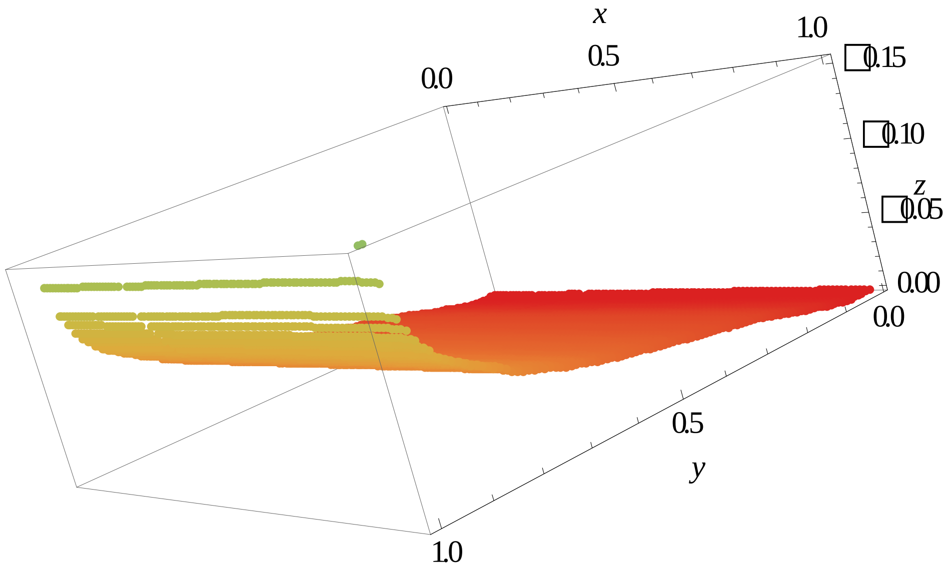


(b) Shared Ride: x = origin density, y = destination density, z = elasticity



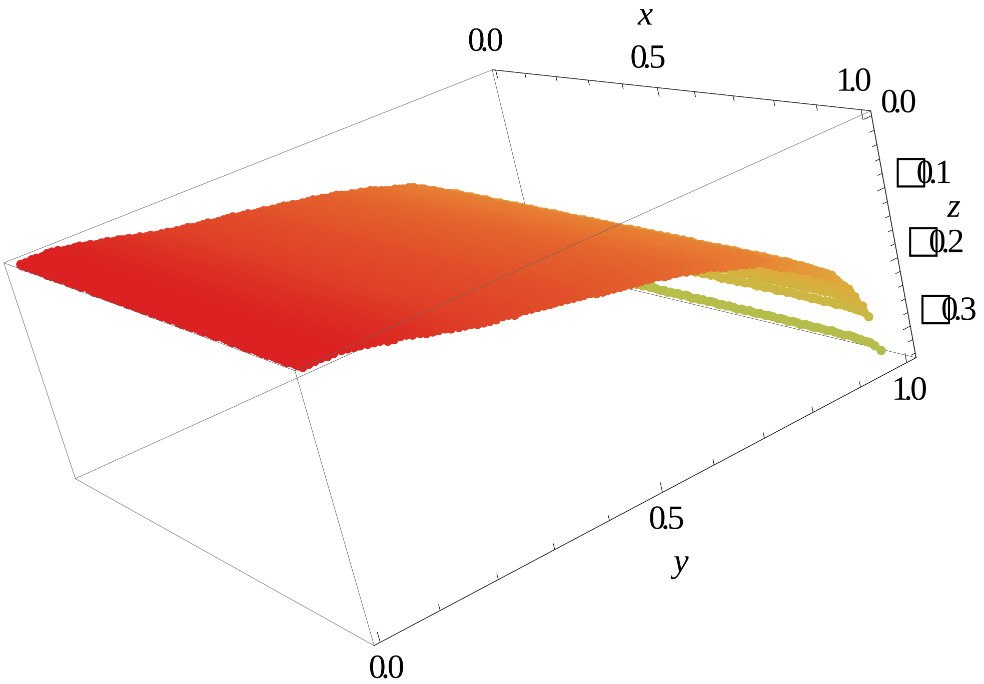
(c) Transit Drive: x = origin density, y = destination density, z = elasticity

Figure 8.9: Elasticity of Origin Population Density

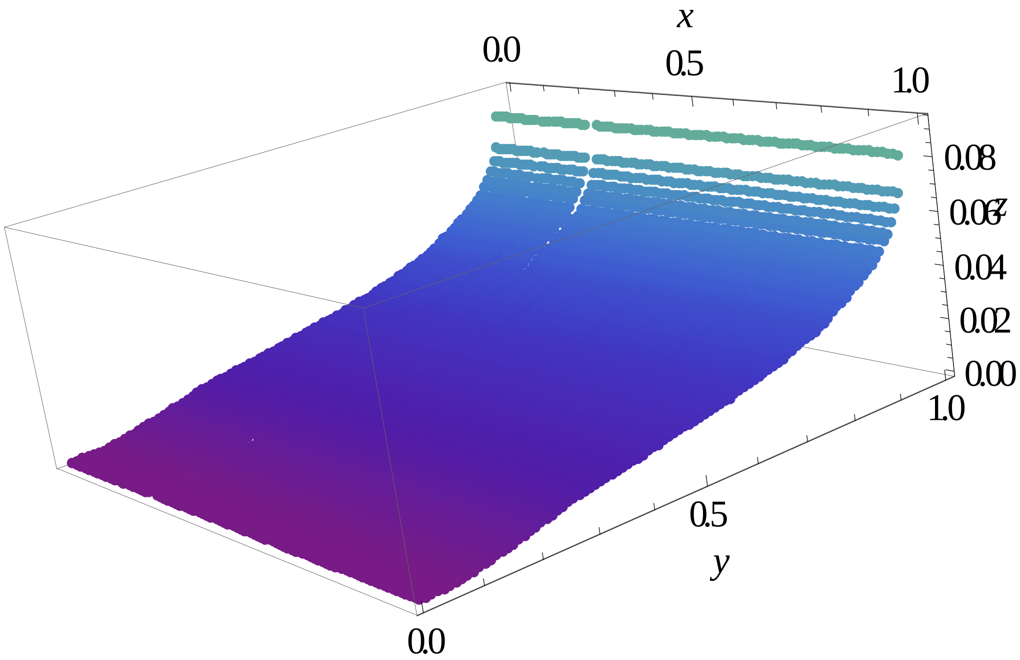


Drive Alone: x = origin density, y = destination density, z = elasticity

Figure 8.10: Elasticity of Destination Population Density

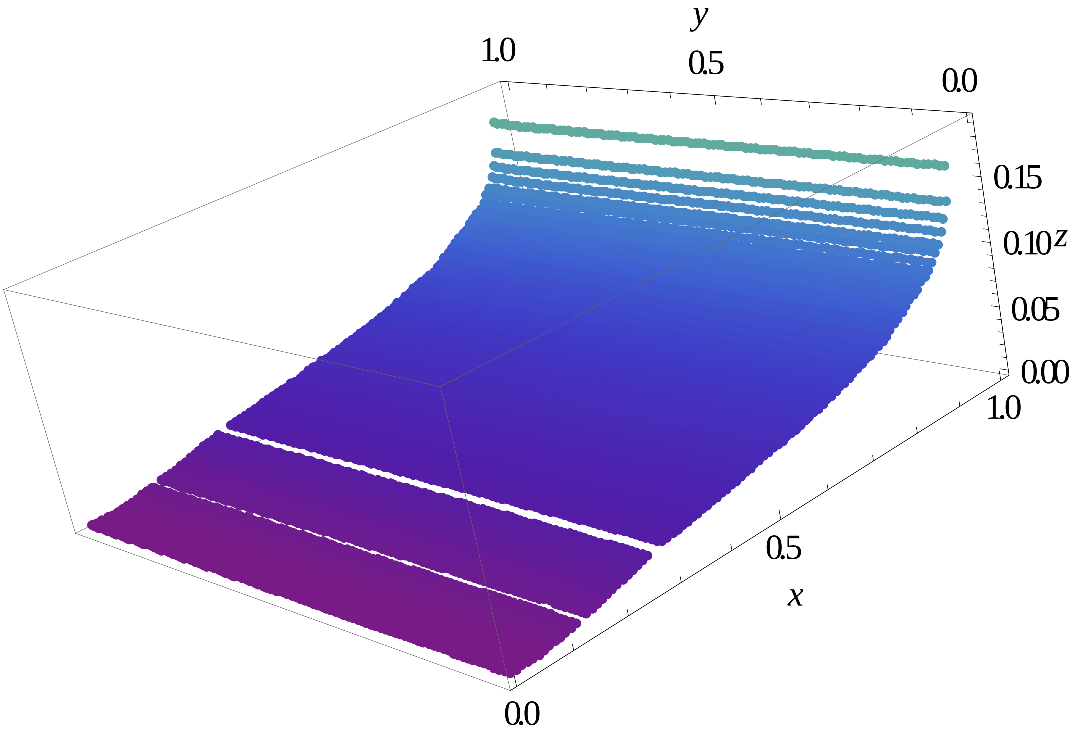


(a) Shared Ride: x = origin density, y = destination density, z = elasticity

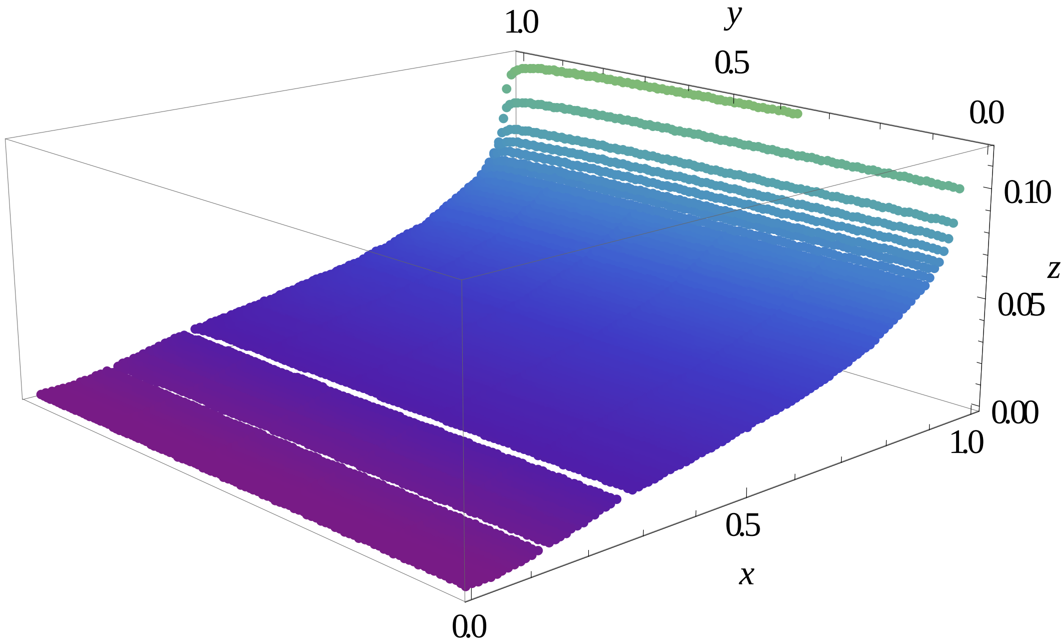


(b) Transit Drive: x = origin density, y = destination density, z = elasticity

Figure 8.11: Elasticity of Destination Population Density

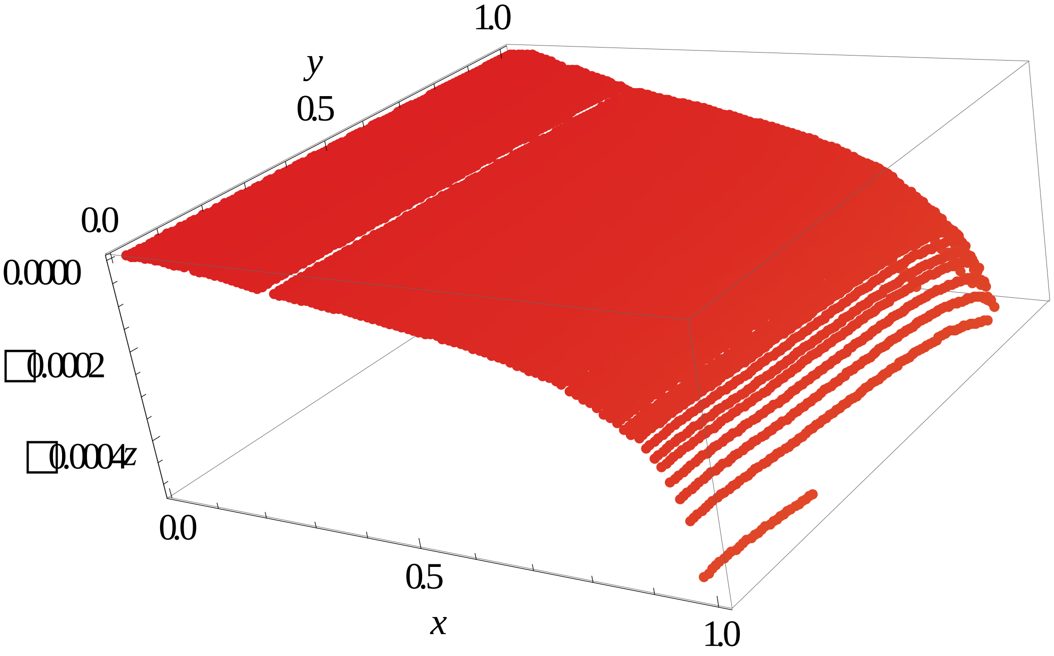


(a) Drive Alone: x = origin density, y = destination density, z = elasticity



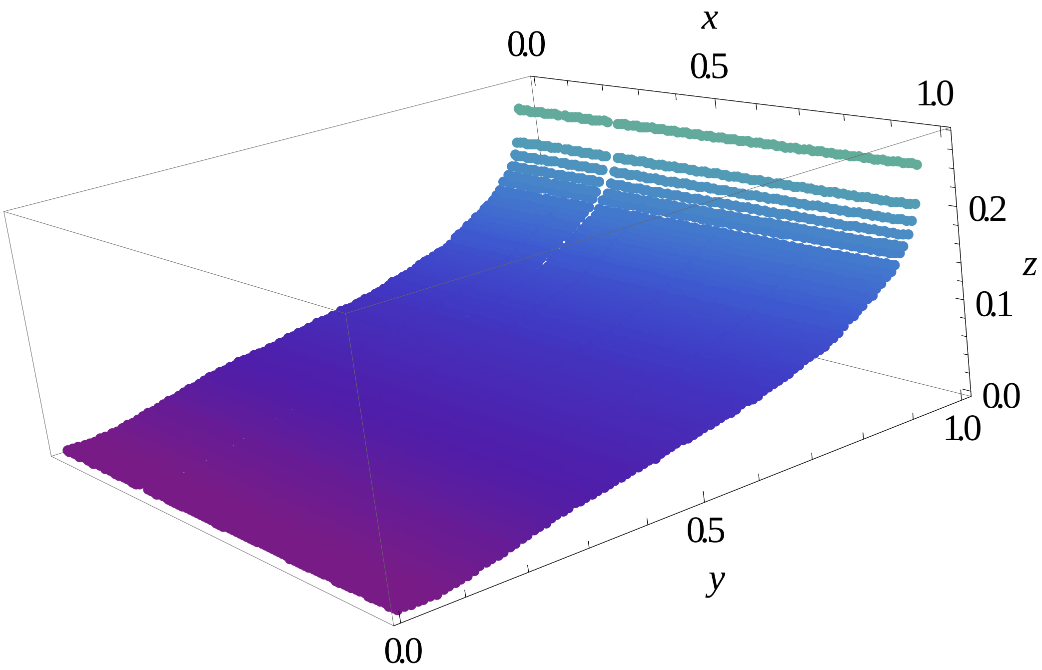
(b) Shared Ride: x = origin density, y = destination density, z = elasticity

Figure 8.12: Cross-Elasticity of Origin Population Density



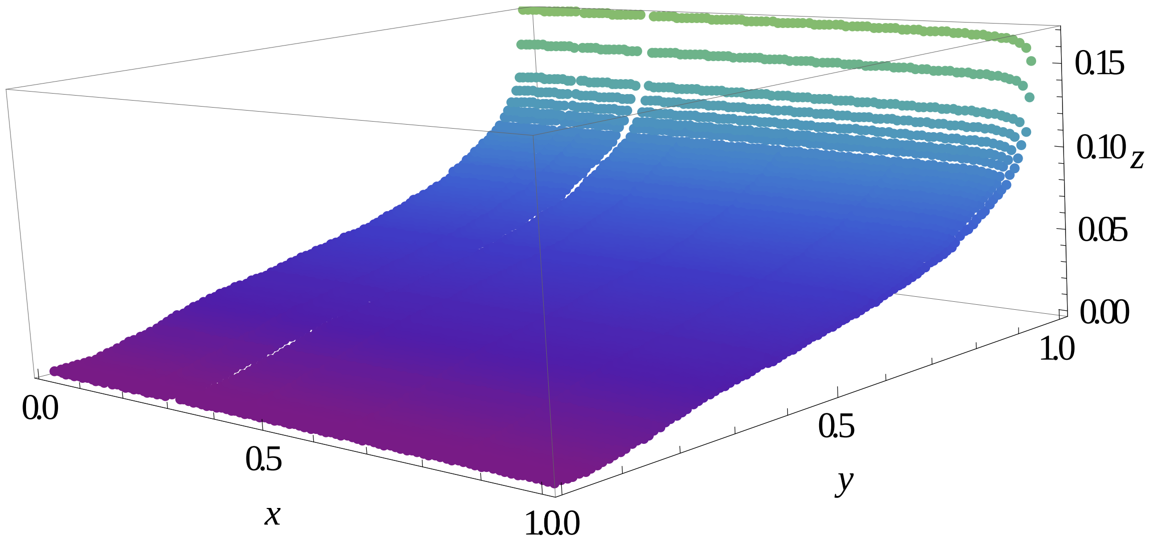
Transit Drive: x = origin density, y = destination density, z = elasticity

Figure 8.13: Cross-Elasticity of Origin Population Density

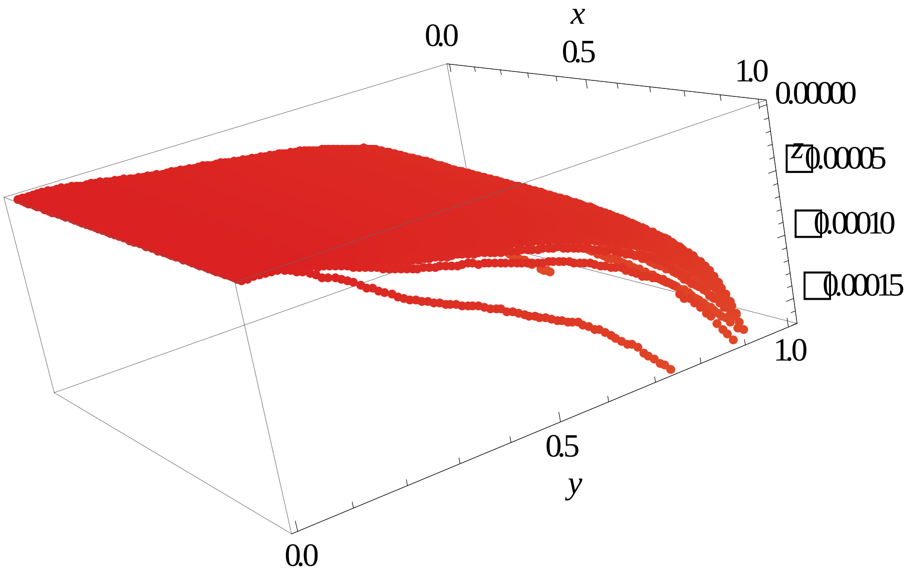


Drive Alone: x = origin density, y = destination density, z = elasticity

Figure 8.14: Cross-Elasticity of Destination Population Density



(a) Shared Ride: x = origin density, y = destination density, z = elasticity



(b) Transit Drive: x = origin density, y = destination density, z = elasticity

Figure 8.15: Cross-Elasticity of Destination Population Density

Figure 8.5 presents the elasticity of origin population density. The elasticity slightly varies by destination population density. The elasticity is the largest for Transit, followed by Shared Ride and Drive Alone. The largest elasticity is at the size of 0.1-0.3. Figure 8.6, 8.7 and 8.8 show the elasticity of destination density, the cross-elasticity of origin density, and the cross-elasticity of destination density. Most of the largest elasticities for Drive Alone and Shared Ride are at the magnitude of 0.15-0.3. However, the elasticity and cross-elasticity for Transit Drive are much smaller, particularly its cross-elasticity. For promoting shifts to transit, the impacts of origin and destination densities are similar to those of travel costs, but inferior to those of travel time.

Chapter 9: Mode Choice Model Discussion

This study explores the impacts of travel time, travel cost, and population density on mode choice, using the 2010 Travel Behavior Inventory. Although the data contain multiple modes, we focused on the competition between transit and personal vehicles, in particular, Drive Alone, Shared Ride, Transit with Drive access, and Transit with Walk access. We found that in the Twin Cities and collar countries, the monetary value of in-vehicle travel time is about \$17.5 per hour and transfer penalty is valued at about \$10, or equivalent to 35 minutes of in-vehicle travel time. Furthermore, for Drive Alone and Shared Ride, destination population density is more important than origin population density, especially for Shared Ride. Density has a critical impact on the choice of transit but it did not show an influence on the modes of access to transit. The largest elasticities for transit are at the size of 1.0, 0.1, 0.3, and 0.1 for travel time, travel cost, origin population density, and destination population density, respectively. This suggests that travel time is the key to promote the shift to transit.

To encourage mode shift to transit, the paramount factor is to reduce travel time of transit or increase travel time of personal vehicles. Travel time of transit includes in-vehicle travel time, access time, and wait time. Transitway programs can reduce in-vehicle travel time. Access time can be reduced by providing park and ride facilities. Walking in a pedestrian-friendly environment can also reduce perceived access time. Increasing transit headways can lower wait time. Providing amenities at transit stop such as newspaper can lower perceived wait time. Since transfer has a substantial penalty, transit agencies should try to avoid transfers. Densification is also important for the choice of personal vehicles vs. transit. Therefore, a successful transitway program requires complimentary land use planning.

Chapter 10: Ridership Model Introduction

Despite their recent growth, transitways operate in an overall public policy environment that still strongly favors the automobile (Shoup, 1997; Su & Zhou, 2012). 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 study as broad a range of policies as possible, while still obtaining results applicable to the Twin Cities region, we focus on peer regions: metropolitan areas identified by the Metropolitan Council as points of comparison to the Twin Cities either for transit system performance or regional transit investment levels (Hiniker, 2013) shows the regions included and the transitway modes present in each. We obtain 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.

The following chapter reviews existing research on the direct ridership modeling approach, as well as local government policies commonly implemented and/or suggested in hopes of supporting transit use. Chapter 3 relates our data collection protocols and research methods in detail, and lays out the logic underlying our research approach. Chapter 4 describes model development, and presents our model specification and results. Chapter 5 explores and illustrates the implications of the model for station area policies by building multiple transit-supportive policy scenarios and predicting their ridership impacts using the estimated model. Chapter 6 concludes with recommendations for policies to pursue with the aim of attracting increased transitway ridership.

Chapter 11: Ridership Model Approach

11.1 Direct Ridership Modeling

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). (R. Cervero, 2006a) 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. (R. Cervero, 2006a; Gutierrez, Cardozo, & Garcia-Palomares, 2011)

Disaggregate mode choice models (as opposed to the aggregate mode split modeling step in four-step models), predict travel behavior at the individual trip level by calculating the probability that a given individual will choose driving, transit or other modes for a given trip. Disaggregate mode-choice modeling frequently employs a discrete choice model, which predicts how individuals will choose among a finite set of alternatives. Specifically, such discrete choice models estimate the probability an individual will choose each considered mode as a function of personal socioeconomic characteristics and the relative utility of each mode. (Ortuzar & Willumsen, 2001) Discrete choice models require disaggregate, revealed preference data on individuals' characteristics, trips and mode choices (such as the Metropolitan Council's Travel Behavior Inventory). These data are used to estimate the observable utility of each mode considered based on quantified characteristics of the traveler (such as income, age or automobile ownership) and of the mode (such as travel time, monetary cost or reliability). (Lancaster, 1966) The probability of a traveler choosing each mode is then calculated by comparing observable utilities. (Ortuzar & Willumsen, 2001) Discrete choice models can produce very robust predictions for relatively small areas (such as transitway corridors), since their observations are individual trips, not trips aggregated by TAZ or some other geographic unit, leading to a highly efficient use of available information. (Spear, 1977)

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. (R. Cervero, 2006a; R. Ewing & Cervero, 2001) In a DRM, any factor with an empirical relationship to transit use can be used to predict ridership. (R. Cervero, 2006a; Kuby, Barranda, & Upchurch, 2004) 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. (Cervero, 2006a) 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. (Lane, DiCarlantonio, & Usvyat, 2006) 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. (R. Cervero, 2006a) 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. (Walters & Cervero, 2003) 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. (Kuby et al., 2004)

11.2 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. (Taylor, Miller, Iseki, & Fink, 2009) 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. (Taylor et al., 2009)

11.2.1 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. (Calthorpe & Mack, 1989; R. Cervero, 1984; R. Cervero & Knockelman, 1997) 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." (R. Cervero, 1994) 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 (Giuliano, 1995), while Crane finds the evidence inconclusive (Crane, 2000)—but the bulk of the literature appears to find some positive evidence. Table 1 shows a selection of research with results supporting the hypothesis that TOD encourages higher rates of transit use and/or lower rates of automobile use.

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. (Tilahun & Fan, 2014)

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. (Guthrie % Fan, 2015; Hess & Lombardi, 2004; Levine & Inam, 2004; Levine, 2005) 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. (Levine & Frank, 2007) 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. (Guthrie & Fan, 2015)

Table 11.1: Selected Research on TOD Impacts

Research	Data	Travel Variables	Supportive findings on mode-choice impacts			
			TOD/traditional nbhd.	Density	Use Diversity	Ped. Design
(Holtzclaw, 1994)	1990 Census, emissions inspection odometer checks	Auto ownwership, VMT*	Yes	Yes	n/a	n/a
(R. Cervero & Gorham, 1995)	1990 Census	Auto, transit & pedestrian mode split	Yes	Yes	n/a	n/a
(Cervero & Knockelman, 1997)	Bay Area Travel Survey (1990-91)	Mode choice for work & non-work trips	n/a	Yes	Yes	Yes
(Evans, Perincherry, & Douglas, 1997)	Street network, transit service, local population & employment data	Transit use	n/a	Yes	n/a	Yes
(Lund, Cervero, & Willson, 2004)	Original survey	Transit use	Yes	No	n/a	Yes
(Handy, Cao, & Mokhtarian, 2005)	Original survey	VMD, frequency of driving/walking	Mixed†	n/a	Mixed†	Mixed†
(Cervero, 2006b)	Original survey	Transit commuting, Mid-day mode choice, access mode	Yes	Yes	Yes	Yes
(H. Lund, 2006)	Original survey	Transit use	Yes	n/a	n/a	n/a
(R. Cervero, 2007)	Original survey	Transit use	Yes	No	No	Yes‡
(R. Ewing & Cervero, 2010)	Meta-analysis of previous empirical research	Transit use, walking, VMT	n/a	Yes	Yes	Yes

*Used transit access to predict lower auto ownership/VMT.

†Handy, et al produced opposite results with two different analysis techniques.

‡Only at destination end of commute trips.

11.2.2 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. (D. Shoup, 2005) 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. (Willson, 2000) 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. (Shiftan & Burd-Eden, 2001; Shiftan & Golani, 2005)

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. (D. Shoup, 2005) 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. (Willson, 2000) 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). (Willson, 2000) 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. (D. C. Shoup, 1995) These findings suggest significant room for public-policy improvement in crafting parking requirements with the goal of transit-friendly communities in mind.

11.2.3 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. (D. Shoup & Willson, 1992) 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. (Williams & Petrait, 1993) 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. (Dill & Wardell, 2007) 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. (Su & Zhou, 2012)

11.2.4 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. (Kim, Ulfarsson, & Hennessy, 2007) 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." (Schwanen & Mokhtarian, 2005) 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. (R. Cervero, 2002)

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). (R. Cervero, 2001)

11.3 From Ridership to Mode-Shift

New, premium transit services like transitways attract riders from a variety of previous modes and/or travel patterns. Some transitway riders often switch from bus service replaced by the transitway, or from parallel bus routes that continue to operate but offer less attractive service than the transitway, others may supplement non-motorized travel with transitway use, while still others may make trips they would not have made otherwise. Finally, some fraction of passengers use the transitway for trips previously made by driving. The latter group creates the mode shift at the heart of this research, and it varies in size considerably.

According to the Before and After Study of the Metro Blue Line conducted for Metro Transit as part of post-construction project documentation for the Federal Transit Administration, 50% of all passengers on the region’s first transitway are new to transit. The study does not directly address auto-to-transit mode shifts, but its finding that 80% of light rail passengers have access to an automobile suggests that at least some significant proportion of new-to-transit riders use light rail trips to replace driving trips. (SRF Consulting Group, 2010)

11.4 Post-Processing

Post-processing refers to a set of techniques to refine ridership modeling results to account for the impacts of elastic phenomena. Post-processing takes the results of a travel demand or ridership model as a jumping-off point, then uses established elasticities to add consideration of factors not implicitly included in the original model. (R. Cervero, 2006a) Post-processing is most commonly employed to account for the impacts of travel-demand management strategies, but in recent years has been used to consider the trip-generation impacts of smart growth and transit-accessible projects as well. (Fehr & Peers, 2005a; Fehr & Peers, 2005b; Walters, Ewing, & Schroeer, 2000)

11.4.1 Car Shedding

The phenomenon of car shedding—the voluntary choice by households, for reasons other than lack of means, to own fewer cars, or even to go without a car altogether—may hold significant promise to increase transit ridership where transit service is sufficiently attractive. Since car shedding households voluntarily become (at least partly) transit-dependent, they may use transit considerably more frequently than traditional choice riders. (R. Cervero, 2006a; R. Ewing, 1998)

Despite this promise, the ridership impacts of car shedding can be difficult to model, as automobile ownership rates are traditionally considered only as causes of transit use, while the car shedding phenomenon suggests that automobile ownership rates are to some extent an effect of transit use as well. Cao, Mokhtarian and Handy, find that neighborhood characteristics impact automobile ownership rates, but only marginally, finding instead that personal attitudes appear more important. Their research primarily concerned differences between traditional and suburban built forms. Their study area likely contains significant inter- and intra-neighborhood differences in transit access which were outside the scope of research, and therefore not explicitly considered. (Cao, Mokhtarian, & Handy, 2007) Hess and Ong, however, find that high levels of land use diversity can decrease the probability of automobile ownership by 31%, suggesting that this decline is largely a consequence of higher availability (and greater convenience) of alternative modes, including walking, cycling and transit. (Hess & Ong, 2001)

Bhat and Guo directly examine the impacts of local built environment characteristics on automobile ownership among residents of Alameda County, California, finding that access to transit service plays a significant role in determining automobile ownership for all households. Specifically, their binary transit availability variable (which did not differentiate between transit modes or service levels) yielded an aggregate-level elasticity of -0.0461, indicating that any access to any type of transit leads to roughly 5% fewer cars in a TAZ. Time required to access a transit stop also played an important role in determining automobile ownership. (Bhat & Guo, 2007)

11.5 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. Finally, post-processing techniques allow for the consideration of elastic phenomena such as car shedding. Put together, these techniques will allow the flexible, forward-looking and realistic projections needed to guide the implementation of beyond-the-rail local policies to enhance the mode-shifting impacts of transitway investments.

Chapter 12: Ridership Model Methods

12.1 Study Regions

We focus on peer regions to the Twin Cities, as defined by the Metropolitan Council for use in either transit system performance comparisons or in regional transit system investment levels. Specifically, we include the Twin Cities and 15 peer regions which had at least one transitway operating in calendar year 2013. Figure 12.1 shows study regions and modes.

12.2 Data Collection

Our 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. We enjoyed an extraordinary degree of cooperation in this phase: every provider contacted eventually provided ridership data.

12.2.1 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. (This is the standard station-level ridership measure in the Twin Cities, and was our first choice in data requests.) 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.

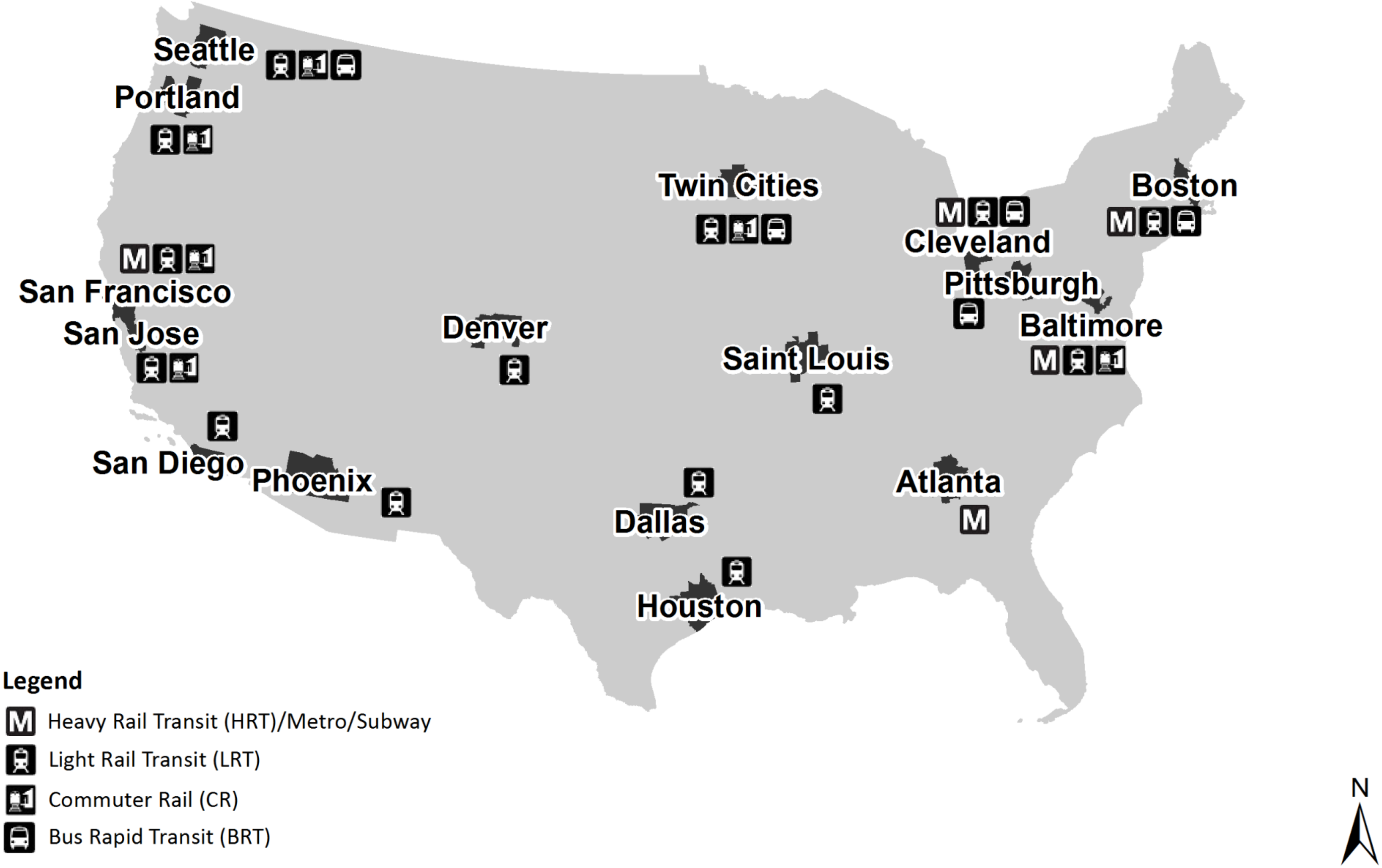


Figure 12.1: Study Regions and Transitway Modes

Also, in addition to a number of modern "New Start" light rail lines, our 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 (there are, apparently, such things as pole-in-the-ground light rail 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.

12.2.2 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. Our data collection initially took the form of an online survey distributed to planning staff in cities containing our study stations. Despite multiple contacts and reminders, we 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, we manually coded remaining cities by using our 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. Please see Appendix A for the full data collection instrument.

12.2.3 Other data sources

Table 12.1 shows the data sources used in the research. In addition to ridership data (as discussed in Sec. 12.2.1 transit providers also supplied General Transit Feed Specification (GTFS) format route and schedule data, either directly or via the GTFS Data Exchange, a crowd-sourced clearinghouse of GTFS data. GTFS is the source data for Google Maps' transit directions feature; based on a set of comma-delimited text files, it provides latitude/longitude coordinates, official name and routes for all transit stops in a system, as well as full timetables for every run of every route (Czebotar, 2015). Built environment and additional transportation system data were obtained from the Environmental Protection Agency's Smart Location Database, a national-scale, block group-level GIS database containing 98 measures of social, economic, built environment and transportation characteristics. Importantly, the Smart Location Database provides nationally comparable data (Ramsey, Bell, Walters, & Jimenez, 2014).

Table 12.1: Public Data Sources for Ridership Modeling

Ridership GTFS	Transit providers
Built environment Transportation system	EPA (Smart Location Database)
Activity	Google (Google Places)
Socioeconomics	American Community Survey

We 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, we downloaded counts of places, both in total and by type within a 100M [CHECK THIS!!!] radius of each transitway station included in the data. We 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. The American Community Survey provided additional socioeconomic data on station area conditions.

12.3 Approach

Figure 12.2 illustrates the basic hypothesis underlying the research. We 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.

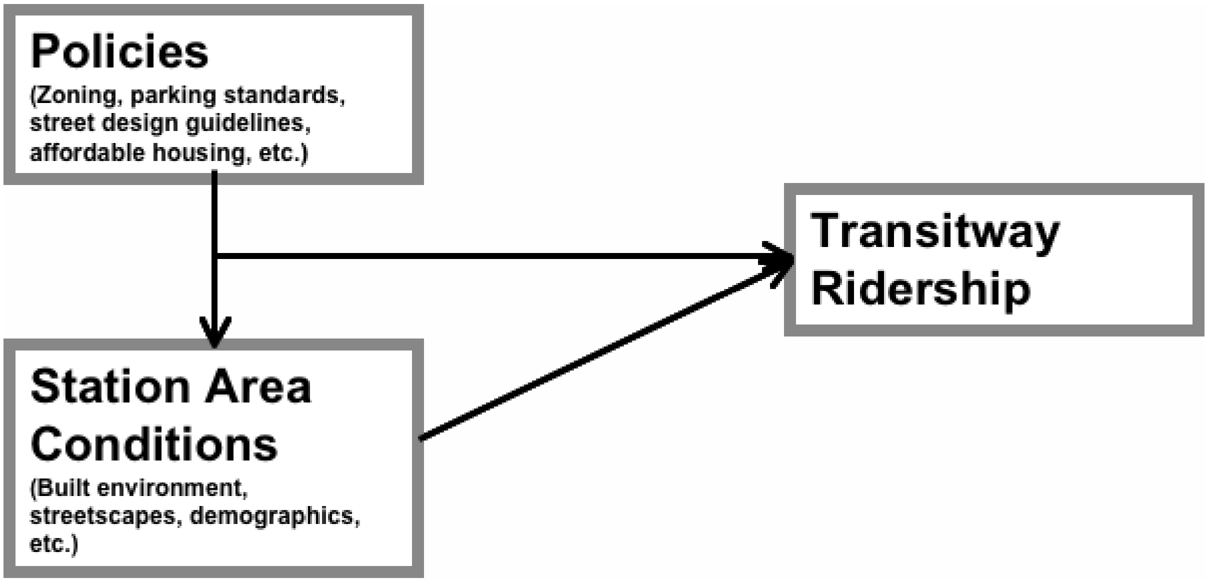


Figure 12.2: Research Hypothesis

We 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.

We initially modeled ridership simply as a function of realized regional and station area characteristics. This allowed us to determine what built environment, social and transit system characteristics were strong predictors of transitway ridership. This model then formed the basis of four subsequent models including transit supportive policies. These models began with a single model primarily including stations in central cities, proceeded to a further single model including the full dataset, and finally evolved into a pair of models stratified by station area activity levels. The following chapter discusses the progression of models in detail and presents results of each.

Chapter 13: Ridership Model Results

13.1 Initial Model

The initial model predicts transitway ridership solely as a function of realized conditions. It establishes a “jumping off point”, so to speak, for the subsequent models including transit supportive policies, by tying the modeling to the transit service, built environment and social factors that have significant impacts on ridership. Going by the research hypothesis illustrated in Figure 12.2, it is only logical to consider the impacts of public policies related to realized conditions which significantly predict ridership. The initial model is a Poisson regression, predicting the response variable boardings as a function of the following explanatory variables:

- **Heavy Rail, BRT, Commuter Rail—**Dummy variables indicating the transitway mode; LRT is omitted as the reference.

- **San Francisco, Dallas, Cleveland, Houston, Seattle, Baltimore, Atlanta, San Diego, Pittsburgh, Denver, Portland, Phoenix—**Dummy variables indicating the region; Twin Cities is omitted as the reference.

- **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.

- **Road network density, Intersection density—**Numbers of street segments and intersections per square mile in the Census block group containing the transitway station. Included as a measure of local transportation network connectivity.

- **Employment accessibility by transit—**Jobs reachable within 45 minutes’ transit travel, in tens of thousands of jobs.

- **Distance from population weighted centroid to transit stop—**The distance in meters from the population-weighted centroid of the census block group containing the station to the nearest transit stop. Included as an overall measure of transit access.

- **Housing units/acre, Jobs/acre—**Measures of residential and commercial density in the census block group containing the station.

- **Employment/household entropy—**A Shannon’s entropy statistic of jobs and households in the census block group containing the station, included as a measure of jobs-housing balance.

- **% of block group employment within ¼ mile of a transitway station—**A measure of employment centralization in the census block group containing the station.

- **Total establishments, Restaurants and food stores, Other stores—**Numbers of Google places within 100M [CHECK!!!] of the station.

Median household income, % Single-person households, % of households with children, % of residents under 18, % of residents ages 40-64, % 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.

Table 13.1 shows the results of the initial ridership model. Likely due in part to a degree of freedom of 774, all explanatory variables are statistically significant, though Commuter Rail only marginally so. In order to distinguish important variables to include in further models, we also produced standardized coefficients from the initial model results. Standardized coefficients describe the coefficient of each variable in terms of that variable’s standard deviation—simply, they put disparate variables in common terms, allowing them to be ordered by the strength of their effects on the response variable. Table 13.2 shows the standardized coefficients in order from strongest positive to strongest negative, with a horizontal rule at zero.

Table 13.1: Ridership Model, Realized Conditions Only

	Response Variable:	**Observat**	813
	Boardings	**Pseudo**	0.81
	Explanatory Variables:	*β*	*IRR*
Mode	**(LRT)**		
	Heavy Rail	1.2851*	3.615
	BRT	- 1.0290*	0.357
	Commuter Rail	0.0106*	1.010
Region	**(Twin Cities)**		
	San Francisco	- 0.5219*	0.593
	Dallas	- 0.8208*	0.440
	Cleveland	- 0.6770*	0.508
	Houston	- 0.1215*	0.885
	Seattle	- 0.2789*	0.756
	Baltimore	- 0.2210*	0.801
	Atlanta	- 0.8208*	0.440
	San Diego	0.4496*	1.567
	Pittsburgh	0.2594*	1.296
	Denver	0.7454*	2.107
	Portland	0.3030*	1.354
	Phoenix	- 0.6263*	0.534
Service	**Number of lines**	0.3977*	1.488
	One direction station	- 0.6380*	0.528
	Terminal station	0.3543*	1.425
Transportation System	**Road network density**	- 0.0088*	0.991
	Intersection density	0.0002*	1.000
	Employment accessibility by transit (by 10,000	- 0.0358*	0.964
	Distance from pop. weighted centroid to transit	- 0.0384*	1.039
Jobs & Housing	**Housing Units/Acre**	- 0.0006*	0.999
	Jobs/Acre	0.0019*	1.001
	Employment/household entropy	0.2686*	1.308
	% of block-group employment with 1/4mi of	0.2298*	1.258
Google Places	**Total establishments**	0.0040*	1.004
	Restaurants & food stores	0.0123*	1.012
	Other stores	0.0094*	1.009
Socioeconomic Characteristics	**Median Household income (by $1,000)**	- 0.0012*	0.998
	% Single-person households	0.0808*	1.084
	% of households with children	- 0.3363*	0.714
	% of residents under age 18	- 0.3630*	0.695
	(% of residents ages 18-39)		
	% of residents ages 40-64	0.4494*	1.567
	% of residents age 65 and over	- 0.7859*	0.455
	% minority population	0.0613*	1.063
	% foreign born	0.5030*	1.653
	% of households where workers > cars	0.2043*	1.226
	Constant	- 8.7195*	

* p<.1; ** p<.05; ***p<.01

Table 13.2: Standardized Coefficients, Initial Model

Relationship with Ridership

Strongest	Heavy Rail	1.534	***
	No. of Lines	1.343	***
	Job Density	1.155	***
	Terminal	1.103	***
	Restaurants/food stores	1.087	***
	Total establishments	1.084	***
	% foreign born	1.084	***
↑	% employment within 1/4mi of transitway	1.079	***
	Other stores	1.061	***
	Jobs/housing entropy	1.058	***
	% residents ages 40-64	1.051	***
+	Intersection density	1.02	***
	% households where workers < cars	1.018	***
	% of single-person households	1.016	***
	% minority residents	1.016	***
	Distance from pop. centroid to transitway	1.01	***
	Commuter rail	1.002	*
	Residential density	0.996	***
	Median household income	0.964	***
—	% residents under age 18	0.962	***
	% households with children	0.941	***
↓	% residents age 65 & over	0.926	***
	Road density	0.922	***
	Job accessibility	0.917	***
	One Direction	0.745	***
Strongest	Bus Rapid Transit	0.607	***

13.2 Policy Models

After estimating the initial model, we proceeded to estimate ridership models including both realized conditions and policies. With policy data coding still underway, we began by estimating a test model based primarily on central city stations, with a sample of suburbs included. This allowed us to build an initial model with the simplicity of a somewhat more homogenous group of policies than would be present in the final data. This model was merely a test, to build understanding of how transit-supportive policies play out in the relatively favorable conditions of central cities.

13.2.1 Initial policy model

In addition to colinearity between policy and built environment variables, we also found colinearity between many different policy variables. For example: all observations with a pro-bicycle infrastructure policy also had a pro-pedestrian infrastructure policy, making it impossible to include bicycle infrastructure as a separate variable. Of the policy variables included in the model, only Pro-sidewalk policy (defined as an explicit municipal policy calling for sidewalks on all streets either in station areas or in the city as a whole) was significant. It’s Incidence Rate Ratio (IRR) of 1.686 indicates that, all else equal, a pro-sidewalk policy yields roughly a 69% increase in boardings. The strength of pro-sidewalk policy found in this model would make it an important focus of subsequent models.

Table 13.3 shows the results of the initial policy model. Again employing Poisson regression, the model is significantly simplified from the previous one by the omission of regional dummy variables (with the model clustered by region instead to account for regional effects), and the focus on a much narrower set of realized built environment variables. In part, a simpler model in terms of variables describing realized conditions was necessitated by colinearity between policy variables and many of the built environment variables included in the initial model.

In addition to colinearity between policy and built environment variables, we also found colinearity between many different policy variables. For example: all observations with a pro-bicycle infrastructure policy also had a pro-pedestrian infrastructure policy, making it impossible to include bicycle infrastructure as a separate variable. Of the policy variables included in the model, only Pro-sidewalk policy (defined as an explicit municipal policy calling for sidewalks on all streets either in station areas or in the city as a whole) was significant. It’s Incidence Rate Ratio (IRR) of 1.686 indicates that, all else equal, a pro-sidewalk policy yields roughly a 69% increase in boardings. The strength of pro-sidewalk policy found in this model would make it an important focus of subsequent models.

Table 13.3: Initial Policy Model

	Response Variable:	**Observations**	685
	Boardings	**Pseudo R^2**	
	Explanatory Variables:	*β*	*IRR*
Mode	**Heavy Rail**	***	2.383
	BRT	***	0.431
	Commuter Rail	*	0.552
Policies	**Pro-Sidewalk Policy**	**	1.686
	Low Parking Ratio Policy		1.064
	Pro-Density Policy		0.938
	Pro-Affordable Housing Policy		0.923
Station Characteristics	**Number of Lines**	***	1.697
	One-Direction Station	***	0.428
	Terminal Station	***	1.821
	Park and Ride	**	1.260
	Station in Central City		1.120
Density	**Housing Units per Acre**		0.997
	Jobs per Acre	***	1.001
Social Characteristics	**Median Income ($1K)**		0.999
	% One-Person Households	**	1.948
	% of Population under 18	*	0.358
	% of Population 65 & over	*	0.456
	% Minority Population		1.110
	% Foreign Born Population	***	2.608
	% of Car-Insufficient Households	***	4.019
	Constant		

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

13.2.2 Final policy models

After completing policy data coding, we re-estimated the model with the complete data set, including a total of 850 observations in 16 regions. Table 13.4 shows the results of the final round of ridership models. As before, we initially estimated a combined model including all 850 observations. Employing a similar specification to the initial policy model shown in In addition to colinearity between policy and built environment variables, we also found colinearity between many different policy variables. For example: all observations with a pro-bicycle infrastructure policy also had a pro-pedestrian infrastructure policy, making it impossible to include bicycle infrastructure as a separate variable. Of the policy variables included in the model, only Pro-sidewalk policy (defined as an explicit municipal policy calling for sidewalks on all streets either in station areas or in the city as a whole) was significant. It's Incidence Rate Ratio (IRR) of 1.686 indicates that, all else equal, a pro-sidewalk policy yields roughly a 69% increase in boardings. The strength of pro-sidewalk policy found in this model would make it an important focus of subsequent models.

Table 13.3 (with Low-parking ratio policy removed due to colinearity with Pro-density policy in the full dataset), the model produced a similar result, though with pro-affordable housing policy significant as well and a smaller, though still significant effect from Pro-sidewalk policy. Upon attempting to including google place data, however, Pro-sidewalk policy became insignificant and Pro-affordable housing policy, though still marginally significant, weakened significantly. As Google place data offers a measure of the activity level in a station area, it seemed highly counter-intuitive that it would make the provision of pedestrian infrastructure insignificant. Suspecting an interaction effect between the two variables, we divided our data just below the 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. These are our final models, shown in the left-most columns of Table 13.4.

All of 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.

Table 13.4: Final Ridership Models

		Combined			*<50 Est.*			*≥50 Est.*		
	Response **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	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	-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 >	1.0443	**	2.8415	1.2660		3.5467	0.8810	**	2.4133
	Constant	6.1176			5.5933			3.8157		

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

- **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. Our model shows that every percentage point increase in households with low automobility yields a 2.4% increase in transitway ridership.

Table 13.5 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.

Table 13.5: Standardized Coefficients, ≥50 Establishments Model

Relationship with Ridership	**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	***

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.

13.2.3 Adding Establishment Types

In the interest of providing additional detail on station area activity types, we also estimated a similar set of models including the same variables as the split policy models described above, with the addition of the percentage of food service businesses and financial businesses. Table 13.6 shows the results of the policy models including establishment type percentages. Once again, Poisson models are employed. Percent of food service/grocery establishments is significant and positive in the combined and at least 50 surrounding establishments models. Percent of financial establishments is marginally significant and strongly positive in the at least 50 establishments model. (This pattern may relate to the prevalence of the financial sector in high ridership generating central business districts.) Pro-sidewalk policy is no longer significant in any of the models, while a station-area pro-density policy is now significant and *negative* in the at least 50 establishments model. Based on the volatile (and counter-intuitive) behavior of the policy variables, there appears to be multicolinearity in play among them and business types.

As a result of these issues, we base our primary conclusions on the model shown in Table 13.4, without percentages of business types included. However, the models in Table 13.6 provide a valuable insight into the relationship between transit-supportive public policies and transitway ridership: as shown in the final models as well, there is a strong interaction between the effects of transit-supportive policies and station area activity. Though, in the end, we specify our models to focus on the effects of the policies, the establishment type models underscore the complementary effects of station area activity in determining transitway ridership.

Table 13.6: Policy Model Including Business Types

			Combined			***< 50 Est.***			***≥ 50 Est.***		
	Response Variable	**Observations**	850			406			444		
	Boardings	**Pseudo R^2**	0.75			0.67			0.80		
	Explanatory Variables		*β*		*IRR*	*β*		*IRR*	*β*		*IRR*
Policies	**Pro-sidewalk policy (binary)**		0.2355		1.2655	0.2671		1.3061	0.2009		1.2225
	Pro-density policy (binary)		-0.0610		0.9408	0.1210		1.1286	-0.2793	**	0.7563
	Pro-affordable housing policy (binary)		0.2725	**	1.3133	0.0865		1.0903	0.3703	***	1.4481
Built Environment	**Number of establishments (count)**		0.0076	***	1.0076	0.0108	**	1.0109	0.0315		1.0321
	% Food service/grocery establishments		1.1762	***	3.2421	0.5238		1.6884	1.2349	**	3.4381
	% Financial establishments		1.5625		4.7706	0.1943		1.2145	2.8702	*	17.6412
	Residential density (housing units/acre)		-0.0038		0.9963	-0.0028		0.9973	-0.0037		0.9963
Station Characteristics	**HRT (binary)**		1.0059	***	2.7344	1.0797	***	2.9437	0.9495	***	2.5844
	BRT (binary)		-0.8759	***	0.4165	-1.1307	***	0.3228	-0.8745	***	0.4171
	CR (binary)		-0.5217	*	0.5935	-0.6878	*	0.5027	-0.2610		0.7703
	Legacy system (binary)		-0.0771		0.9258	-0.3472		0.7067	0.0530		1.0545
	Number of lines (count)		0.3342	***	1.3968	0.4306	***	1.5381	0.2713	***	1.3116
	One-direction station (binary)		-0.8573	***	0.4243	-0.8568	***	0.4245	-0.8032	***	0.4479
	Terminal station (binary)		0.5013	***	1.6509	0.7389	***	2.0935	0.2993	***	1.3489
	Park and ride (binary)		0.1679		1.1828	0.1780	*	1.1948	0.0135		1.0136
	Distance from CBD (kM)		-0.0175	***	0.9826	-0.0113	***	0.9887	-0.0218	***	0.9785
	Distance from next station (kM)		0.0815	*	1.0849	0.0515		1.0528	0.1314	**	1.1405
Social Characteristics	**Median income ($1K)**		-0.0005		0.9995	0.0000		1.0000	-0.0005		0.9995
	% 1-person households		-0.2049		0.8147	0.6583		1.9314	-0.5187	***	0.5953
	% population < 18 yr.		-1.4033	***	0.2458	-0.6996		0.4968	-1.9696	***	0.1395
	% population ≥ 65 yr.		-0.5687	**	0.5663	-1.5520	***	0.2118	-0.3194		0.7266
	% minority population		-0.1578		0.8540	-0.1606		0.8516	-0.1904		0.8266
	% foreign born residents		0.9206	***	2.5108	0.9204	*	2.5104	0.9417	***	2.5644
	% households where workers > cars		0.9489	***	2.5830	1.2173		3.3780	0.8523	***	2.3451
	Constant		6.0972	***		5.5441	***		5.0643	***	

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

13.3 Model Predictions

As a hypothetical example of the implications of our model results, the following section presents predicted boardings for archetypal stations in our data. By computing marginal effects for different transit-supportive policies while holding other variables constant, we can illustrate the real-world impacts of the results. Figure 13.1 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

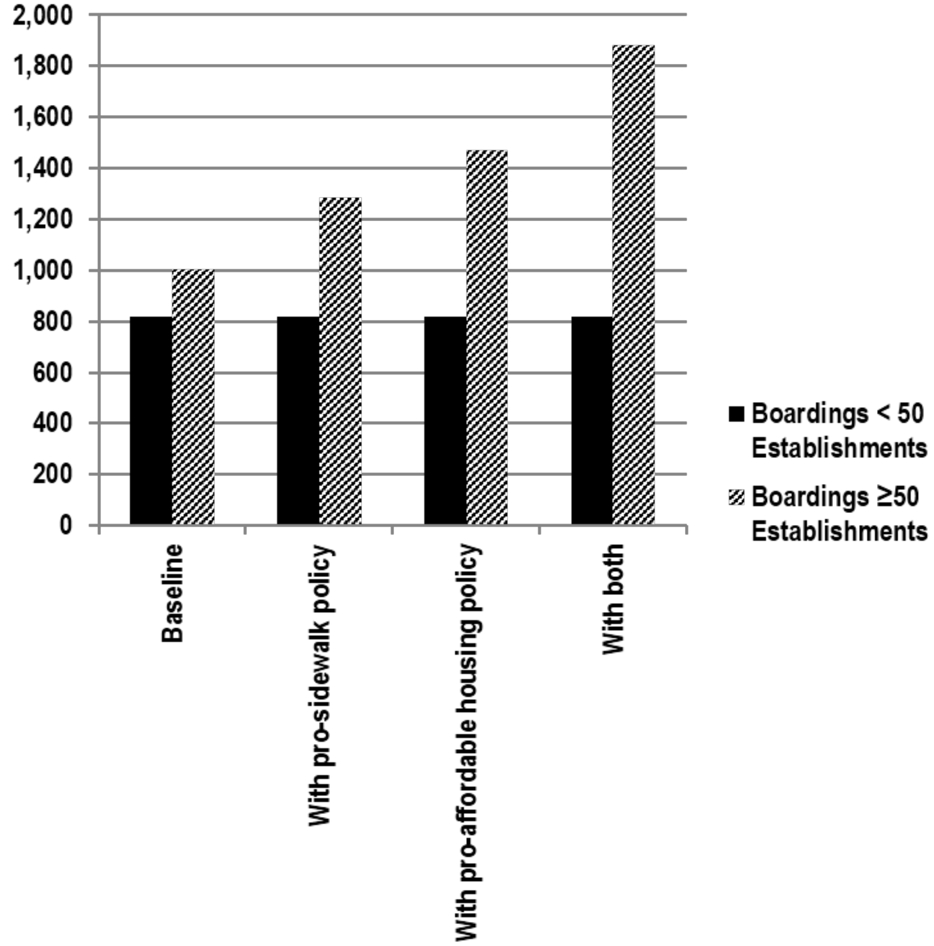


Figure 13.1: Model Predictions

In every case, the typical station with less than 50 surrounding establishments attracts 819 average weekday boardings. No policy variables are significant in the relevant model: we predict 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.

13.4 Example

The Beaverton Transit Center light rail station in Beaverton, Oregon (a suburb of Portland) is the highest ridership light rail station that is neither a terminal, nor a park-and-ride facility nor located in a central business district. The City of Beaverton has both a station area-focused pro-affordable housing policy and an explicit pro-sidewalk policy. It attracts 4,894 average weekday boardings, roughly 400 more than the East Bank station on the Twin Cities' Metro Green Line. As may be seen in Figure 13.2, the station is located in an area with a decidedly late 20th Century suburban built form. Blocks are large and irregular, streets wind, and a great deal of area is devoted to parking. Based on aerial imagery, the station appears to be in a singularly transit-unfriendly area. However, Figure 13.3 and Figure 13.4 paint a different picture. Taken from the perspective of a pedestrian at the primary entrance to the light rail station, these pictures show a human-scale environment, with ubiquitous pedestrian infrastructure and a variety of potential destinations within view via a reasonably convenient walking route. Also, in the upper half of Figure 13.2, as well as Figure 13.5 and Figure 13.6, can be seen a significant quantity of relatively dense, modest housing both in the forms of site-built multifamily units and single-family manufactured housing—often one of the most affordable suburban housing types. These photographs are an anecdote that cannot indicate causality. Even so, they offer a powerful illustration of the model results in action.

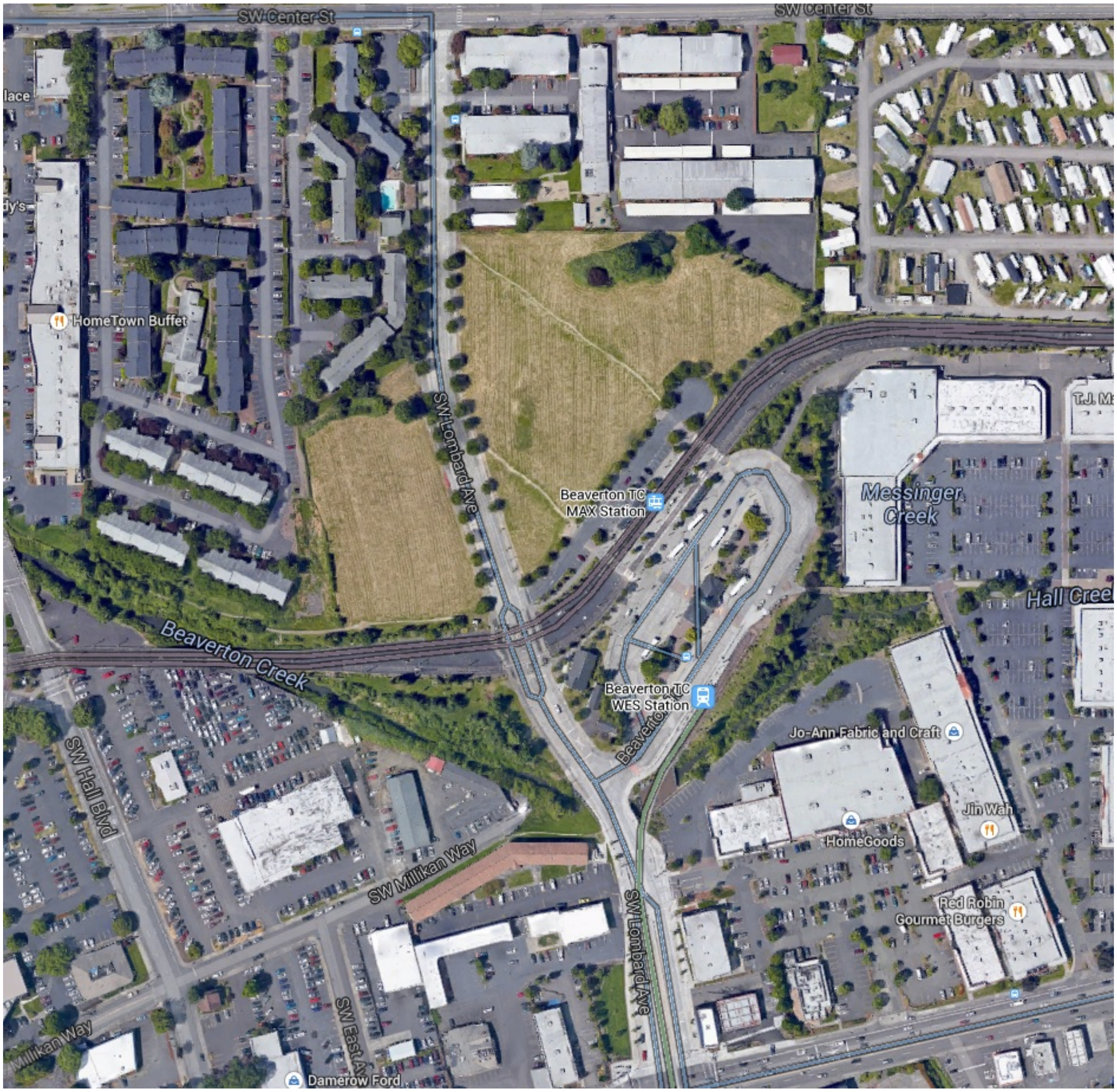


Figure 13.2: Beaverton Transit Center, Aerial View

(Image source: Google Maps.)

Figure 13.3: Beaverton Transit Center, Pedestrian Entrance

(Image source: Google Maps.)

Figure 13.4: Beaverton Transit Center, Surroundings

(Image source: Google Maps.)

Figure 13.5: Beaverton Transit Center, Nearby Apartments

(Image source: Google Maps.)

Figure 13.6: Beaverton Transit Center, Nearby Manufactured Housing

(Image source: Google Maps.)

Chapter 14: Ridership Model Discussion

Under the right circumstances, transit-supportive public policies matter. While the actual built environment is crucial, our 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. We do not dispute the merit of that rationale, but our 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.

Based on the modeling results, we can clearly 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 we cannot recommend them for station areas with more sparse surroundings. We believe our models show not 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 "good news", so to speak, is that the cities containing the overwhelming majority of currently operating Twin Cities transitway stations already have both station area-focused pro-affordable housing policies and explicit, pro-sidewalk policies applying either to station areas or generally within their limits. In fact, all cities served by the Metro Blue Line, Metro Red Line and Metro Green Line have such policies. As the regional transitway system expands, however, the extensions of the Green and Blue Lines will be almost entirely suburban, serving municipalities which have never been served by transitways before. Based on our results, it will be crucial to continue the implementation of station area-focused pro-affordable housing policies and explicit, pro-sidewalk policies in suburban cities as the buildout of the regional transitway system progresses. In addition, as lower-density suburbs can be expected to have fewer neighborhood-scale destinations within close radii of their transitway stations, it will be critical to promote development of the fine-scaled neighborhood centers around suburban transitway stations that our models indicate will be necessary for such policies to have the desired effect.

Our 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. Our findings lay out an agenda for cities in the Twin Cities region served (or 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.

Chapter 15: Conclusion

The impacts of transitways on regional travel patterns depend upon considerably more than transitways themselves. The literature review and case studies in Part I demonstrate the importance of high-quality, regional transit in achieving high transit mode shares, but also show that metropolitan characteristics such as built form and parking policy are crucial as well.

The Twin Cities mode choice model echoes the dual importance of urban form and transit service quality, specifically as it compares to automotive levels of service. Part II finds density at trip origins and destinations to be crucial, with greater importance for destination density, in predicting transit use. The model also finds transit travel times compared with automotive travel times to be an important predictor of the decision to drive or use transit.

Part III focuses specifically on station area characteristics and policies, specifically finding strong positive effects on ridership for provision of pedestrian infrastructure and affordable housing in station areas. These effects are only significant, however, in station areas with high activity levels. Once again, the effects of transitways are bound up with, and dependent on the places they serve.

The disparate approaches (and even specific questions) of the three parts of this report make the central thread of their findings all the more striking. Attracting the greatest number of travelers out of their cars and onto transitways requires building excellent transitways, but it also requires a focus on the broader transportation system and on the form of the region itself.

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Appendix A
Policy Coding Instrument

Transit and Development: Policy Questionnaire (Cities)

City Information

* Required

Region *

Please select your region

Mark only one oval.

Atlanta, GA *Skip to question 2.*
Baltimore, MD *Skip to question 3.*
Boston, MA *Skip to question 4.*
Cleveland, OH *Skip to question 5.*
Dallas-Fort Worth, TX *Skip to question 6.*
Denver, CO *Skip to question 7.*
Houston, TX *Skip to question 8.*
Phoenix, AZ *Skip to question 9.*
Pittsburgh, PA *Skip to question 10.*
Portland, OR *Skip to question 11.*
San Diego, CA *Skip to question 12.*
San Francisco, CA *Skip to question 13.*
San Jose, CA *Skip to question 14.*
Seattle, WA *Skip to question 15.*
Saint Louis, MO (includes cities in IL) *Skip to question 16.*
Twin Cities, MN *Skip to question 17.*

1.

Atlanta

Please select your city, township, town or borough *

Mark only one oval.

Atlanta, GA *Skip to question 18.*
Chamblee, GA *Skip to question 18.*
College Park, GA *Skip to question 18.*
Decatur, GA *Skip to question 18.*
Doraville, GA *Skip to question 18.*

2.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Baltimore

Please select your city, township, town or borough *

Mark only one oval.

Aberdeen, MD *Skip to question 18.*
Arbutus, MD *Skip to question 18.*
Baltimore, MD *Skip to question 18.*
Baltimore Highlands, MD *Skip to question 18.*
Brooklyn Park, MD *Skip to question 18.*
Cockeysville, MD *Skip to question 18.*
Edgewood, MD *Skip to question 18.*
Elkridge, MD *Skip to question 18.*
Ferndale, MD *Skip to question 18.*
Jessup, MD *Skip to question 18.*
Linthicum, MD *Skip to question 18.*
Lochearn, MD *Skip to question 18.*
Lutherville, MD *Skip to question 18.*
Maryland City, MD *Skip to question 18.*
Middle River, MD *Skip to question 18.*

North Laurel, MD *Skip to question 18.*
Odenton, MD *Skip to question 18.*
Owings Mills, MD *Skip to question 18.*
Perryville, MD *Skip to question 18.*
Pikesville, MD *Skip to question 18.*
Timonium, MD *Skip to question 18.*
Towson, MD *Skip to question 18.*
3.
For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Boston

Please select your city, township, town or borough *
Mark only one oval.
Boston, MA *Skip to question 18.*
Braintree, MA *Skip to question 18.*
Brookline, MA *Skip to question 18.*
Cambridge, MA *Skip to question 18.*
Malden, MA *Skip to question 18.*
Medford, MA *Skip to question 18.*
Milton, MA *Skip to question 18.*
Newton, MA *Skip to question 18.*
Quincy, MA *Skip to question 18.*
Revere, MA *Skip to question 18.*
Somerville, MA *Skip to question 18.*
4.
For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Cleveland

Please select your city, township, town or borough *
Mark only one oval.
Cleveland, OH *Skip to question 18.*
East Cleveland, OH *Skip to question 18.*
Shaker Heights, OH *Skip to question 18.*
5.
For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Dallas-Fort Worth

Please select your city, township, town or borough *
Mark only one oval.
Carrollton, TX *Skip to question 18.*
Dallas, TX *Skip to question 18.*
Fort Worth, TX *Skip to question 18.*
Plano, TX *Skip to question 18.*
6.
For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Denver

Please select your city, township, town or borough *
Mark only one oval.
Denver, CO *Skip to question 18.*

Golden, CO *Skip to question 18.*
Northeast Jefferson, CO *Skip to question 18.*
Sedalia, CO *Skip to question 18.*
South Aurora, CO *Skip to question 18.*
Southwest Arapahoe, CO *Skip to question 18.*

7.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Houston

Please select your city, township, town or borough *

Mark only one oval.

Houston, TX *Skip to question 18.*

8.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Phoenix

Please select your city, township, town or borough *

Mark only one oval.

Phoenix, AZ *Skip to question 18.*

9.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Pittsburgh

Please select your city, township, town or borough *

Mark only one oval.

Bethel Park, PA *Skip to question 18.*
Carnegie, PA *Skip to question 18.*
Castle Shannon, PA *Skip to question 18.*
Crafton, PA *Skip to question 18.*
Dormont, PA *Skip to question 18.*
Ingram, PA *Skip to question 18.*
Mount Lebanon, PA *Skip to question 18.*
Pittsburgh, PA *Skip to question 18.*
South Park, PA *Skip to question 18.*
Swissvale, PA *Skip to question 18.*
Wilkinsburg, PA *Skip to question 18.*

10.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Portland

Please select your city, township, town or borough *

Mark only one oval.

Beaverton, OR *Skip to question 18.*
Gresham, OR *Skip to question 18.*
Hillsboro, OR *Skip to question 18.*
Northwest Clackamas, OR *Skip to question 18.*
Portland, OR *Skip to question 18.*
Rockcreek, OR *Skip to question 18.*
Wilsonville, OR *Skip to question 18.*

11.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

San Diego

Please select your city, township, town or borough *

Mark only one oval.

San Diego, CA *Skip to question 18.*

12\.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

San Francisco

Please select your city, township, town or borough *

Mark only one oval.

Berkeley, CA *Skip to question 18.*
Fremont, CA *Skip to question 18.*
Hayward, CA *Skip to question 18.*
Livermore, CA *Skip to question 18.*
Oakland, CA *Skip to question 18.*
Pleasanton, CA *Skip to question 18.*
San Francisco, CA *Skip to question 18.*
San Mateo, CA *Skip to question 18.*

13\.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

San Jose

Please select your city, township, town or borough *

Mark only one oval.

San Jose, CA *Skip to question 18.*
South Santa Clara Valley, CA *Skip to question 18.*

14\.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Seattle

Please select your city, township, town or borough *

Mark only one oval.

Auburn, WA *Skip to question 18.*
Federal Way, WA *Skip to question 18.*
Seattle, WA *Skip to question 18.*

15\.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Saint Louis

Includes related cities from Illinois

Please select your city, township, town or borough *

Mark only one oval.

Airport, MO *Skip to question 18.*
Belleville, IL *Skip to question 18.*
Clayton, MO *Skip to question 18.*
East St. Louis, IL *Skip to question 18.*
Hadley, MO *Skip to question 18.*
Normandy, MO *Skip to question 18.*

Saint Louis, MO *Skip to question 18.*
Shiloh Valley, IL *Skip to question 18.*
St. Clair, IL *Skip to question 18.*
University, MO *Skip to question 18.*
16.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Twin Cities

Please select your city, township, town or borough *
Mark only one oval.
Anoka, MN *Skip to question 18.*
Apple Valley, MN *Skip to question 18.*
Big Lake, MN *Skip to question 18.*
Bloomington, MN *Skip to question 18.*
Coon Rapids, MN *Skip to question 18.*
Eagan, MN *Skip to question 18.*
Elk River, MN *Skip to question 18.*
Fort Snelling, MN *Skip to question 18.*
Fridley, MN *Skip to question 18.*
Minneapolis, MN *Skip to question 18.*
Ramsey, MN *Skip to question 18.*
St. Paul, MN *Skip to question 18.*
17.

For the following questions please make sure your answers represent the policies of the city selected here rather than the overall region in which they are located.

Section A: Land Use

Policies intended to influence station area land use
1) Does the city have the following land use policies in station areas?
Please answer all questions
Mark only one oval per row.
Yes No
Permit higher residential and/or commercial densities than elsewhere?
Permit greater diversity of land uses than elsewhere?
Permit multiple uses in the same building?
18.
2) Are there any other station area related land use policies besides the ones discussed above implemented in your city?
If yes, describe the policies below. If no, type "No" in the textbox below.
19.

If you answered “No” to both Questions 1 (all options) and 2, skip to the next page by clicking "Continue" at the bottom of the page. If not, finish the questions below before continuing to the next page.

3) How does the city implement policies mentioned in the previous questions?
Please answer all questions.
Mark only one oval per row.

Yes No
Overlay districts?
Traditional zoning?
Form based codes?
20.

4) Could you provide links for or information on where documentation regarding the policies discussed in this section can be found?

21.

Section B: Station Area Design

Policies setting standards for the design of station areas including the bicycle and pedestrian environments

5) Does the city have policies calling for the following in station areas?

Please answer all questions

Mark only one oval per row.

Yes No
Sidewalks along streets?
Buffers such as street trees, plantings or boulevard strips between sidewalks and traffic lanes?
Bike lanes or paths along major streets?
Traffic calming elements?
Adequate lighting?
Public art or design elements?
Locating parking to encourage pedestrian use (e.g. restricting parking to the back of buildings)?
22.

6) Are there any other design features besides the ones discussed above implemented in station areas in your city?

If yes, describe the policies below. If no, type "No" in the textbox below.

23.

7) Does the city have a bike sharing system?

Mark only one oval.

Yes
No
24.

If you answered “No” to both Questions 5 (all options) and 6, skip to the next page by clicking "Continue" at the bottom of the page. If not, finish the questions below before continuing to the next page.

8) What official documents call for the provision of the design features mentioned in the previous questions?

Please answer all questions.

Mark only one oval per row.

Yes No
Complete street policy?
Subdivision regulations?
Specific station area development plans?
Street design guidelines?

Comprehensive plan and/or
amendment?
25.
9) Could you provide links for or information on where documentation regarding the policies discussed in this section can be found?
26.

Section C: Parking Policy

Policies dealing with parking standards and subsidies
10) Does the city have the following parking related policies in station areas?
Please answer all questions
Mark only one oval per row.
Yes No
Provide for lower off-street parking
standards than elsewhere?
A maximum allowed parking
requirement?
Collaborate with private owners to
create joint parking facilities?
27.
11) Are there any other station area related parking policies besides the ones discussed above implemented in your city?
If yes, describe the policies below. If no, type "No" in the textbox below.
28.

If you answered “No” to both Questions 10 (all options) and 11, skip to the next page by clicking "Continue" at the bottom of the page. If not, finish the questions below before continuing to the next page.

12) How does the city implement the policies mentioned in the previous questions?
Please answer all questions.
Mark only one oval per row.
Yes No
Overlay districts?
Traditional zoning and/or
subdivision regulation (existing or
through modifications)?
29.
13) Could you provide links for or information on where documentation regarding the policies discussed in this section can be found?
30.

Section D: Development Related Policy

Policies impacting development in station areas
14) Does the city have specific redevelopment plans focused on station areas?
Mark only one oval.
Yes
No
31.
15) Does the city do the following to encourage development in station areas?
Please answer all questions
Mark only one oval per row.
Yes No

Encourage joint development or public-private partnership?
Engage in land acquisition or assembly?
Provide tax credits or other financial incentives to developers?
Use Tax Increment Financing as a development tool?
Work continually with communities around station areas to establish community needs, foster longer term partnerships and generate interest in potential development opportunities?
Have dedicated funds for the promotion of Transit Oriented Development?
Have policies encouraging the siting of public buildings (e.g. Town Hall, schools etc.) near transit stations?
32.

16) Could you provide links for or information on where documentation regarding the policies discussed in the previous questions can be found?
33.

17) How many--if any--full and/or part time staff does the city have dedicated to promoting Transit Oriented Development?
Mark only one oval per row.
None 1-2 3-4 5 or more
a) Full Time Staff
b) Part Time Staff
34.

Affordable Housing

Policies impacting affordable housing in station areas

18) Does the city have any of the following policies related to affordable housing in station areas?
Please answer all questions
Mark only one oval per row.
Yes No
Preserve existing affordable housing stock?
Create new affordable housing?
Minimum requirements for percentage of affordable housing?
35.

If you answered “No” to Question 18 (all options), skip to the next page by clicking "Continue" at the bottom of the page. If not, finish the questions below before continuing to the next page.

19) Which of the following tools does the city use to implement its affordable housing policies in station areas?
Please answer all questions

Mark only one oval per row.
Yes No
Zoning (Inclusionary zoning and/or density bonuses for affordable housing)?
Targeted tax increment financing or other value-capture strategies for low-income housing?
Rent controls or condominium conversion controls?
Land banking or transfer tax programs?
Local affordable housing trust funds?
Low Income Housing Tax Credits?
Ongoing affordable housing operating subsidies?
Local tax abatements for low-income or senior housing?
Local programs that provide mortgage or other home ownership assistance for lower income and senior households?
36.

20) Could you provide links for or information on where documentation regarding the policies discussed in this section can be found?
37.

Section E: Employer Transit Benefits

Policies dealing with employer transit pass programs

21) Does the region's primary transit provider offer volume-discounted transit passes to employers?
Mark only one oval.
Yes
No
38.

22) Does the city provide any incentives to employers (like tax credits) for encouraging their employees to use transit?
Mark only one oval.
Yes
No
39.

23) Could you provide links for or information on where documentation regarding the policies discussed in this section can be found?
40.

Thank you for your time!

Could we contact you if we have any follow up questions?
If yes, please give us your contact information. (email and/or phone number)
41.
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